Institute of Ocean Sciences

1981

ANNUAL REVIEW OF ACTIVITIES

Institute
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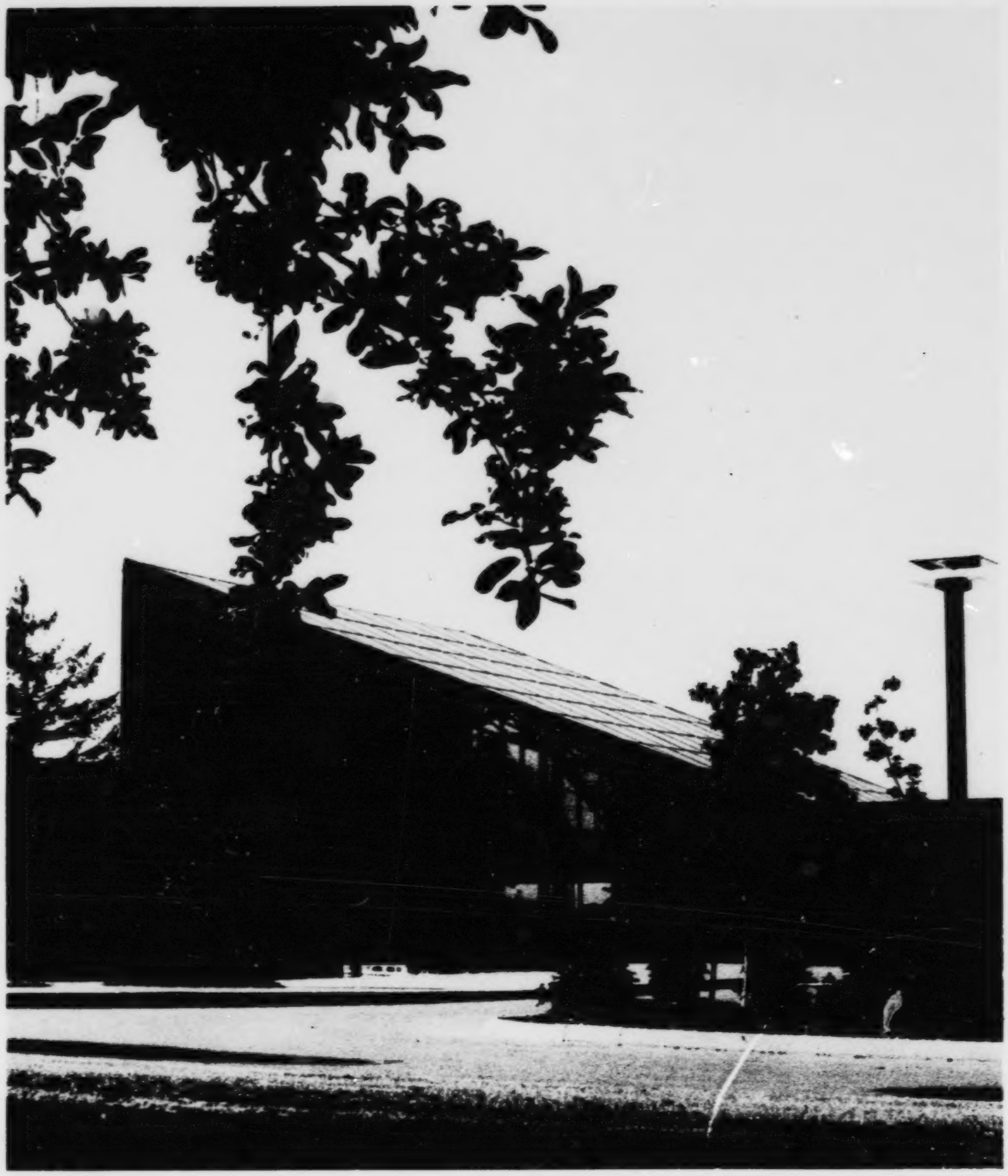
Sciences



1981 ANNUAL REVIEW OF ACTIVITIES

Institute of Ocean Sciences

PATRICIA BAY, SIDNEY, B.C.

Government of Canada   Gouvernement du Canada

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DEPARTMENT OF FISHERIES AND OCEANS

Director-General's Foreword

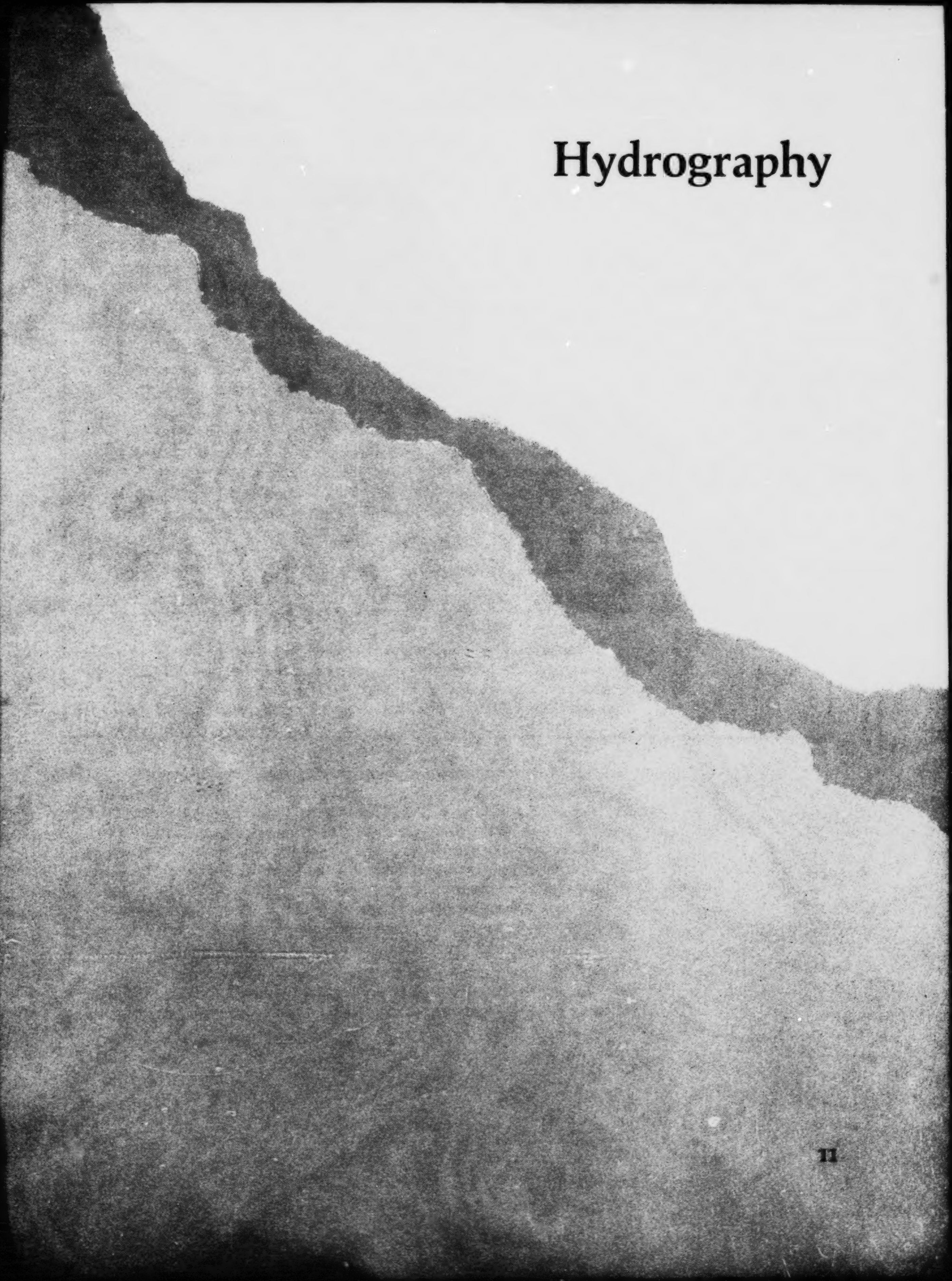
One of the tasks of Ocean Science and Surveys Pacific is to respond to problems arising in the development of natural resources that require hydrographic and oceanographic knowledge for their solution. In 1981 OSS Pacific became involved in two major projects of this type both of which will require substantial effort for the next 3 - 4 years. Provision of hydrographic information to enable safe passage of tankers from the Beaufort Sea to the east is one of these; an assessment of the impact, on the ocean environment, of tailings released into Alice Arm from a molybdenum mine is the other.

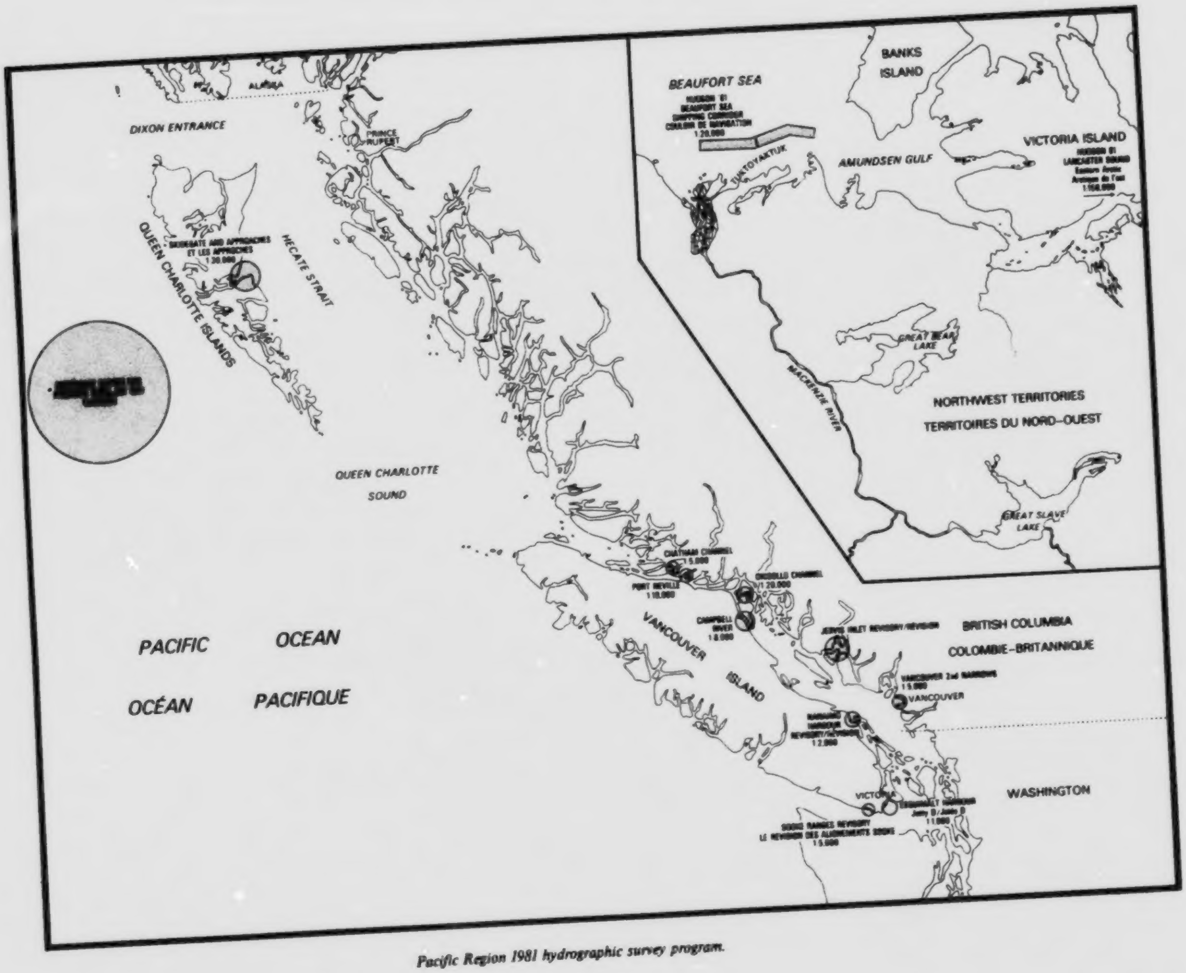
Tankers moving eastward in the Beaufort Sea to the Northwest Passage cross areas where pingos create shoals that are a hazard to these large vessels. With production of oil envisioned in the near future it has become necessary to survey a lane through which the vessels may pass safely. A corridor ten miles wide was chosen, and the survey started in summer of 1981 with CSS *Hudson* on loan from the Bedford Institute of Oceanography. Fifty percent of the corridor was surveyed and it is planned to continue in succeeding years with charter vessels.

Deposition of tailings from the AMAX molybdenum mine into Alice Arm Inlet commenced early this year. The disposal of the tailings into the inlet caused concern that they could adversely affect the environment and local fisheries. A first response to this has been to monitor the tailings' plume to see that its depth and extent conformed with guidelines previously specified. Following the monitoring a three year research program was started to look at basic problems in dispersal of mine tailings in an inlet using the plume in Alice Arm as a case history.

The above projects, together with other responses to practical problems, meant that the region placed considerable emphasis on applied research and survey during 1981. However, it is not intended that the region should diminish its long term effort devoted to understanding the ocean and to improving techniques of measurement and survey. Considerable progress in these areas has been made throughout the year; the improved knowledge of the waters of the continental shelf acquired through the CODE experiment, and major developments in automated cartography, are examples. Physical oceanography has been strengthened with the addition of two theoreticians to better balance the total effort in physics, but progress in chemical and biological oceanogrpaphy is disappointingly slow due to the very small staffs in these two divisions. I am hopeful that this will be recognized and the resources necessary to develop both disciplines made available in the future.

Hydrography





Pacific Region 1981 hydrographic survey program.

The main objective of the Hydrographic Division is to provide accurate, timely bathymetric and navigational information in the form of nautical charts, tide tables, and sailing directions for commercial and recreational users. Additional data are provided to other federal agencies, industry, universities, environment groups, and the general public.

The Division carried out activities in the following important areas in 1981: surveys by CSS *Hudson* in the Beaufort Sea and associated research; resurveys and revisory surveys for the continuing charting program on the Pacific coast; further studies in vessel positioning conducted by the Navigation Group; and a market analysis to determine market potential for Pacific Region charts and user requirements.

Final design modifications were completed for the CSS *Wm. J. Stewart* replacement vessel and a contract for construction is expected in 1982. Construction of survey launches for this vessel was initiated during the year and delivery is expected in 1982.

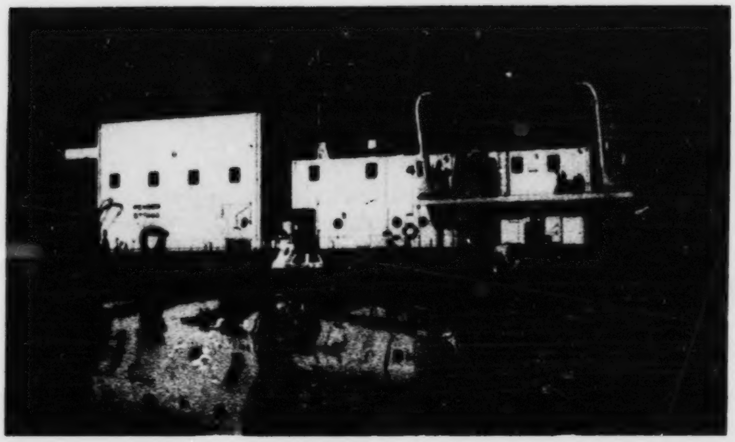
The Regional Director of Hydrography acted as a consultant to the Government of Ireland, studying the requirement and feasibility of establishing an Irish Hydrographic Service. His report was submitted in April and is now being reviewed by the appropriate Irish authorities.

Field Hydrography

The Field Hydrography Section is responsible for conducting hydrographic surveys of B.C. coastal, western Arctic, and navigable inland waters of the Pacific Region, in order to ensure that requirements for navigational information are met. Alterations of, and additions to, traffic routes, types and sizes of vessels, harbours, bottom topography and coastlines — all require an ongoing survey and resurvey program.

The barge *Pender* was again assigned to hydrographic field surveys for a two month period in 1981. A large scale chart will be produced using the information gathered during the 1981 Okisollo Channel survey. After this project was completed, the survey party moved to Vancouver Harbour on assignment for the Ministry of Transport. A survey of Skidegate Inlet and approaches, previously surveyed by the British Admiralty in 1911 was begun with logistical support being provided by CSS *Richardson.* The final survey of the year for this party was undertaken in Campbell River where two field sheets, at a large scale, were completed by the end of the season. *(Contact: B.M. Lusk.)*

CSS *Richardson* also provided support for a survey party in Port Neville, Chatham Channel; these were resurveys of areas originally done in the 1920s. A revisory survey was also carried out from the *Richardson*



Barge Pender and launches in Okisollo Channel (Octopus Islands)

in Jervis Inlet where some further data was required to update a previous survey. Later in the season large scale surveys of a newly-dredged area in Nanaimo Harbour was carried out at the request of the Ministry of Transport and a wharf in Esquimalt Harbour was resurveyed at the request of the Department of National Defence. *(Contact: J.V. Crowley.)*

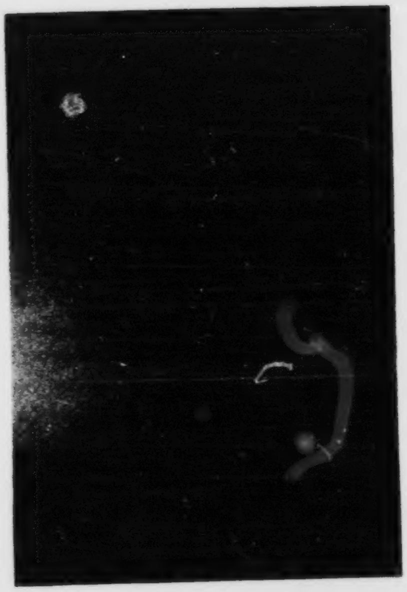
In mid-September the region's Navigation Group carried out further monitoring of the Loran C patterns in the southern Vancouver Island area. These investigations will supply correct time delays and more accurate propagation information for new, latticed charts in southern areas. Early in the year, this same group carried out Accufix-Loran C investigations in the western Arctic to assist further navigation. *(Contact: A.R. Mortimer.)*

CSS *Hudson,* equipped with five survey launches left Victoria on July 6 for the western Arctic. A large-scale, fully automated hydrographic survey of a 10 mile wide, 170 mile long shipping corridor, through the area of the Beaufort Sea known to contain Pingo-Like Features (PLFs), was commenced on July 17. The survey launches ran in shifts for 16 hours per day collecting soundings on parallel lines 100 metres apart while *Hudson* swept the area with side-scan sonar. Despite poor weather, 52% of the corridor was completed before *Hudson* departed from the Beaufort Sea on September 4. The remainder of the season was spent conducting a multidisciplinary survey in Lancaster Sound. *(Contact: A.D. O'Connor.)*

Revisory surveys of Victoria, Vancouver and Nanaimo harbours and the Strait of Georgia from Victoria to Port Hardy were also carried out.

Sailing Directions

The eighth edition of the *British Columbia Coast Sailing Directions (North*



ARGO positioning system tower erected by survey personnel in the western Arctic

Four of the survey launches that gathered sounding information in the Beaufort Sea (Hudson 81)

Portion), Volume II, was published in May. This edition includes new information on vessel traffic management, tidal streams, ports, Loran C, seabed, search and rescue, and regulations. *Volume I, (Southern Portion),* and *Volume II* are published in alternate years.

The fifth edition of *Small Craft Guide, Volume I, Port Alberni to Campbell River including the Gulf Islands,* was also published in May. This publication contains extensive revisions concerning passages in the Gulf Islands. A new edition of the companion, *Volume II, Boundary Bay to Cortes Island,* will be published in 1982.

Helicopter photography operations and revisory surveys were carried out to improve and update these publications.

Hydrographic Development

A new PDP-11/34 based computer system and peripherals were acquired early in the year. Current sounding selection software running on the PDP-8 computers was transferred to the new computer. All existing programs were adapted for compatability with the new plotter and a program was written which allows quick and accurate verification and editing of selected sounding points using a graphics terminal.

In July, the complete package was installed on CSS *Hudson* for the Beaufort Sea survey program. During the Arctic surveys, two eight hour processing shifts were required daily to keep up with the volume of data produced. Typically, sounding plots were produced for four launches within four hours of their return to *Hudson*.

The system performed admirably throughout the survey. Several software "bugs" were identified and corrected.

Final plotting of the data was delayed due to unanticipated problems with the plotting program caused by both the immense quantity of the input data, and by the extreme scale change requested. Although corrective action was taken to produce this year's plots, a major rewrite of this software is indicated.

Chart Production and Distribution

The regional Chart Production and Distribution Section is responsible for the processing of all survey and other data into new charts and publications and for the timely distribution to dealers, and directly to users.

Twelve new Pacific region charts were produced in 1981; nine by the region and three by headquarters. In addition, 42 new editions (including one by headquarters), 34 reprints (12 by headquarters), three overprints, eight patches, and 110 Notices to Mariners were completed.

The first two charts, L/C 3606 Juan de Fuca Strait and 7686 Police Point and approaches (N.W.T.), were produced completely utilizing automated systems.

Continuing the transition to metric format, the 1:40,000 series from Victoria to Nanaimo were completed along with four 1:50,000 series for the west coast of Vancouver Island.

Ministry of Transport (MOT) ships' masters participated in a meeting at the Institute concerning the updating of charts for the western Arctic. A meeting, hosted by the chart production staff, regarding the surveying and charting of the Fraser River, was attended by MOT, Navigable Waters Protection Act and Department of Public Works personnel.

Several major developments in Automated Cartography occurred in 1981. The new custom-made digitizing system was delivered; this included a more accurate table, a special hydrographic cursor for digitizing soundings, and a swivel cursor to enable smooth digitizing of continuous lines.

Computer software underwent extensive changes including implementation of the Digital Data Library (DDL) on the Univac 1100/60.

The DDL will enable Pacific Region to archive graphic files on magnetic tape for long term storage.

The demand for graphic and other information from the Technical Records group continued to increase during 1981; up 61% over the previous year. Similarly, requests for information to update Sailing Directions and Small Craft Guides increased 21%. The number of MAREP reports (the Canadian Power Squadron's Marine Reporting Program) fell to 262, compared to 450 in 1980.

The move towards cyclical printing for most charts, started in 1978, has now begun to show good results. Hand amendments have been reduced by 35% despite an increase in chart sales. This has allowed a considerable cost saving in just three years and has also reduced the amount of wastage of cancelled stock by 70%. In 1981, a total of 1,348,585 hand amendments were made to 163,437 charts.

A market analysis survey conducted during the summer months elicited user compliments and criticisms about Pacific region's charts and publications. As a direct result of the analysis, a system of advance ordering will be implemented for the 1982 tide tables.

In 1981 there were two editions of the Chart Dealers Newsletter and six press releases issued. There were 45 chart dealership inspections, 28 new dealerships approved, 28 withdrawn, and 12 new Small Craft Guide dealerships approved. During the year, Pacific region distributed 203,913 charts, 78,687 publications and 22,318 catalogues and other free publications.

Wrapping area in chart distribution centre

Tidal and Current Surveys

This program provides tidal, current and water level data, along with other information and expertise, for the Canadian west coast and western Arctic. A network of permanent and temporary tidal gauges is maintained for operational and research purposes.

The task of analysing 175 data records from current meters and bottom-mounted pressure gauges, obtained during the Coastal Ocean Dynamics Experiment (CODE) off the west coast of Vancouver Island, continued. Large diurnal currents have been found on the shelf north of Juan de Fuca Strait. These currents can be attributed to continental shelf waves, driven by the diurnal tide. *(Contact: W. Crawford and W.S. Huggett.)*

A current meter installed at Race Rocks in the Strait of Juan de Fuca was recovered after one year of operation. Records have been analysed and current velocity predictions for Race Passage have been made. *(Contact: M.J. Woodward.)*

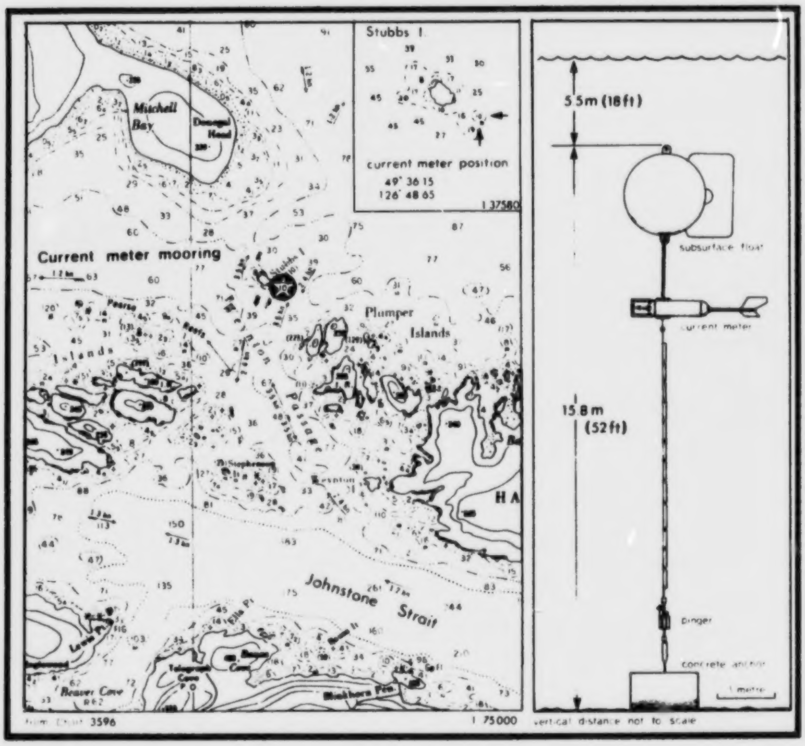


Chart showing Stubbs Islands location of current meter and its description

Work on the inclusion of the salt wedge into the Fraser River tidal model continued. Many field observations were carried out to verify this model. *(Contact: A.B. Ages.)*

Data collection and tide graph processing from temporary and permanent tide gauges continued. In the western Arctic temporary gauges were operated at four to eight week periods at Garry Island, Atkinson Point, Cape Dalhousie and Baillie Island. For the second year, gauges at Gold River, Tahsis and Zeballos were operated for a cooperative project with Pacific Geoscience Centre (PGC) to determine tilting of Vancouver Island. *(Contact: F.E. Stephenson.)*

Diving Unit

During 1981, 123 dives were made on the Pacific coast and in the western Arctic in support of the oceanographic and hydrographic work of the Institute.

In particular, for the Hydrographic Division, several tide gauges were installed, inspected and/or serviced. Studies of seiches were carried out in Juan de Fuca Strait and Haro Strait for Ocean Physics Divison and the Pacific Geoscience Centre. *(Contact: F.E. Stephenson.)*

Tsunamis

A historical study of all tsunamis recorded on Canada's west coast ports is in progress, and has provided a basis for determining how frequently destructive waves may be expected. Primary evidence of past events is obtained from the tide records of permanent gauging stations. Other sources, such as newspaper accounts and diaries are being explored for information about those events that have been experienced before tide stations were operating. The waves from Japan's great Sanriku tsunami of June 15, 1896 are of particular interest.

Results of the tsunami frequency studies are being used by consulting engineers in investigating proposed sites for liquid natural gas terminals, and by planners in making recommendations for land use options in low lying coastal areas.

Active co-operation is being extended by the IOS Tsunami Unit to the International Tsunami Warning System. Effort is being directed towards increased automation of tsunami detection and communications, so that the earliest possible warning can be provided to all threatened coasts in the Pacific when potentially destructive waves occur. A concept of regional warning systems is being developed for the southern Pacific as a possible means of improving response times. The B.C. Earthquake and Tsunami Working Group is continuing to upgrade its procedures for public warning and possible evacuation. Within the Canadian Hydrographic Service techniques have been developed for surveying wave runup and post-tsunami damage.

Research is beginning on submarine landslides as a possible source of tsunamis that may impact on Canadian coasts. Evidence of past occurrences is being collected. *(Contact: S. Wigen.)*

Engineering Services

Engineering Services provides electronics and mechanical engineering and technical support to the research, surveys and ship operations. The Division also provides the industrial liaison, contract support and special programs interface for the Institute.

Electronic Engineering Development

Major electronics projects in 1981 focussed on *Hudson 81* preparations, acoustic engineering support, and long-term developments for Arctic hydrography.

Development, coordination, and implementation of a PDP-11 based field data processing system for hydrography, development and implementation of a navigation module to permit straight-line steering, and a GPIB/SAIL/RS232 (real time data provision system) interface for PHAS (portable hydrographic acquisition system) to accommodate the new ARGO positioning system were accomplished for the *Hudson* expedition.

A new 200 kHz, one-degree beamwidth transducer was specified, acquired, and implemented into the system for the acoustic doppler current measurement project. Numerous modifications were made to the doppler system to improve sensitivity and signal-to-noise ratio. A sonar and doppler recording system for oilwell blow-out studies was designed and implemented and a contract for an acoustic positioning system for the submersible *Pisces* was supervised.

Long-range projects in support of Arctic hydrography, funded through the High Arctic Research Program (HARP), included continued development of a launch autopilot system, a contract to grey-scale depths as an alternative to numbers and contours, and a system for the computerized deployment of survey launches.

Numerous other electronics projects for various IOS groups were pursued. These included a plankton counting and sizing system, a new datalogging system, a five-channel frequency counter, a microprocessor-based Aanderaa-format data translater, a partial pressure carbon dioxide ($pC0_2$) microcontroller, and continuing SAIL development. *(Contact: T. Curran.)*

Mechanical Support

Mechanical design and fabrication projects included mounting brackets for acoustic and optical transducers, a cooling jacket for column chromatography, a sediment trap and a transparent air separator. *(Contact: T. Curran.)*

Institute Electronics

Preparations for the *Hudson* cruise involved extensive modifications to existing equipment, trials of new equipment, and the outfitting of five survey launches.

In addition, staff were trained in the maintenance of the new ARGO positioning system, the PDP-11/34 processing system, the new depth sounders and digitizers, and the complex navigation and interface modifications to the PHAS.

All preparation work, including test, installation of equipment and spares, and training of personnel, was designed to ensure continuity of the survey. Three technologists were assigned to the *Hudson* cruise; two on the ship and one at Tuktoyaktuk to service the ARGO positioning system. *(Contact: R. Taylor.)*

Industrial Liaison and Contracting

The Institute of Ocean Sciences has a policy of conducting a significant portion of its program through private sector contracts. The fostering of government/industry assistance in the marine industries is pursued via the D.S.S. Unsolicited Proposal Program and the Program for Industry/Laboratory Participation (PILP). Liaison and support in these areas is provided by Engineering Services. During the 1981-82 fiscal year the total level of science contracts, exclusive of ship charters, exceeded $2.6 million. Two PILP proposals were initiated during 1981-82 in response to IOS technology transfer efforts, and although neither of these has yet to result in a contract, both are still active. IOS will continue to pursue a very active role in technology transfer programs over the next few years. *(Contact: J.V. Watt.)*

Oceanography

The IOS oceanography program comprises research in physics, chemistry and ecology. Knowledge and understanding of ocean processes, marine life, and environmental quality are pursued to meet the challenge of existing and potential problems regarding industrial development in nearshore and offshore areas, climate, navigation, and marine resource management and development.

Dissemination of research results is generally undertaken through the open literature and, high on the list of IOS priorities, is the active encouragement of technology transfer between the private and public sectors.

Major achievements during 1981 included good progress on CODE (Coastal Ocean Dynamics Experiment) data recovery and analysis, extensive Arctic data compilation and review, CO_2 studies as part of the Hudson 81 research cruise, preparatory work for the major N.W. Passage field program in 1982, and the successful completion of toxicology studies.

In addition, program plans were altered to contribute to the Fisheries and Oceans mine tailings monitoring program in Alice Arm and vicinity. This work covered daily surveys of salinity, temperature and turbidity, and water samples. IOS will continue next year to use the Alice Arm/Observatory Inlet area as a study site to carry out ongoing coastal research as it relates to the deposition of tailings.

Ocean Physics

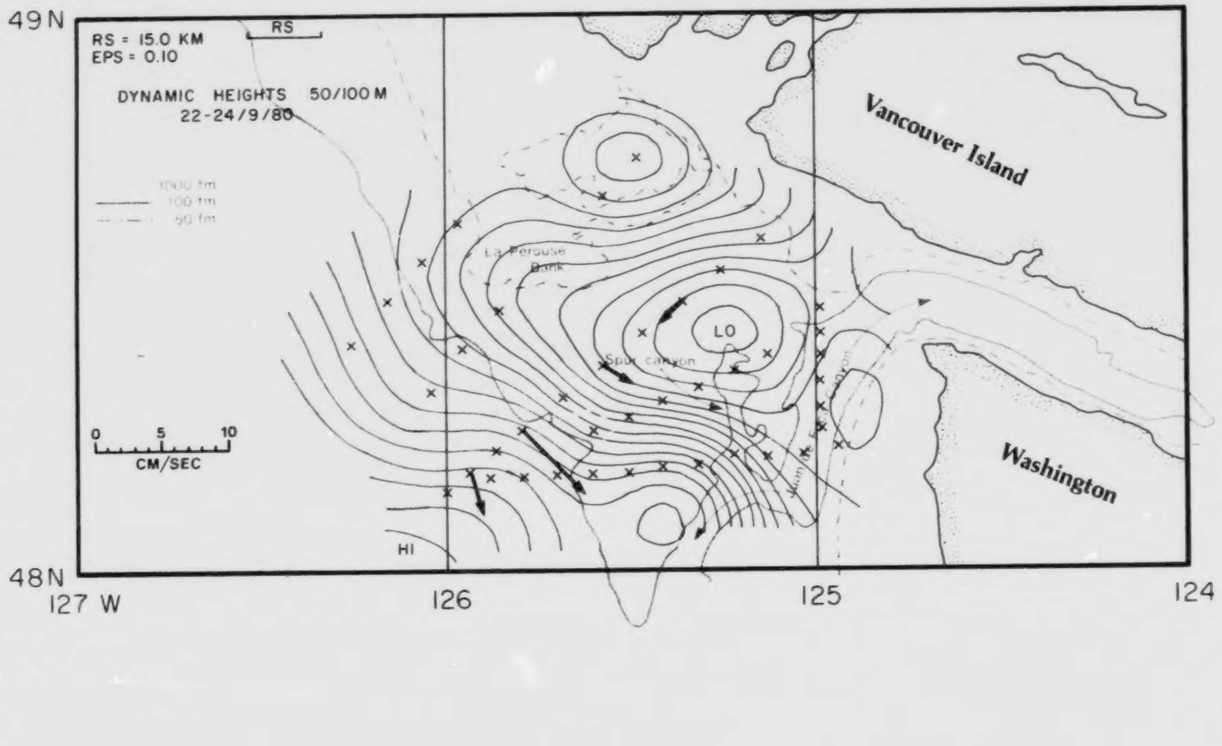
The Ocean Physics program is designed to increase the understanding of physical properties, processes, and phenomena in Canada's Pacific Ocean and in the western Arctic. Nearshore, and coastal area estuarine research is required to respond to water and land use issues. Offshore, deep-ocean and Arctic studies will have influence on the course of industrial development. With air-sea interactions included, the total physical oceanography thrust will move further forward to reliable prediction in areas of environmental quality, renewable and non-renewable resource development, climate and navigation.

Highlights during 1981 included the confirmation of the salt-fingering process (ocean mixing transferring heat and salt at different rates), the compilation of the final data from the weatherships, completed analysis of the 1977 Queen Charlotte Sound CTD (current, temperature, depth) data, and the corroboration of suspected anomalies in tidal records for M'Clure Strait and Viscount Melville Channel through numerical modelling work.

Coastal Zone Oceanography

The major aim of the Coastal Zone Oceanography program is to advance the understanding of the dynamics of coastal processes, mixing, the circulation of estuaries and of the exchanges between shelf and inshore waters. Phenomena investigated include: upwelling, coastal currents, tidal mixing, the interaction of tidal flows with topography and the circulation that this type of interaction induces. This year the Ocean Mixing section was amalgamated with Coastal Zone Oceanography to facilitate, with instrumentation currently under development, the pursuit of mixing processes in inshore and coastal waters. Studies on microstructure, salt-fingering and other mixing processes in the deep ocean continued.

Dynamic height contours between 50m and 100m for a cruise in late summer 1980. The contours show the presence of a large eddy off Vancouver Island. The gradient of dynamic height yields current shear between 50m and 100m. The shear vectors are plotted and the agreement indicates substantial geostrophy in the field. The overlay shows the relationship to the bottom topography. The northern end of the spur canyon always seems to lie at the centre of the eddy suggesting some dynamical relationship.



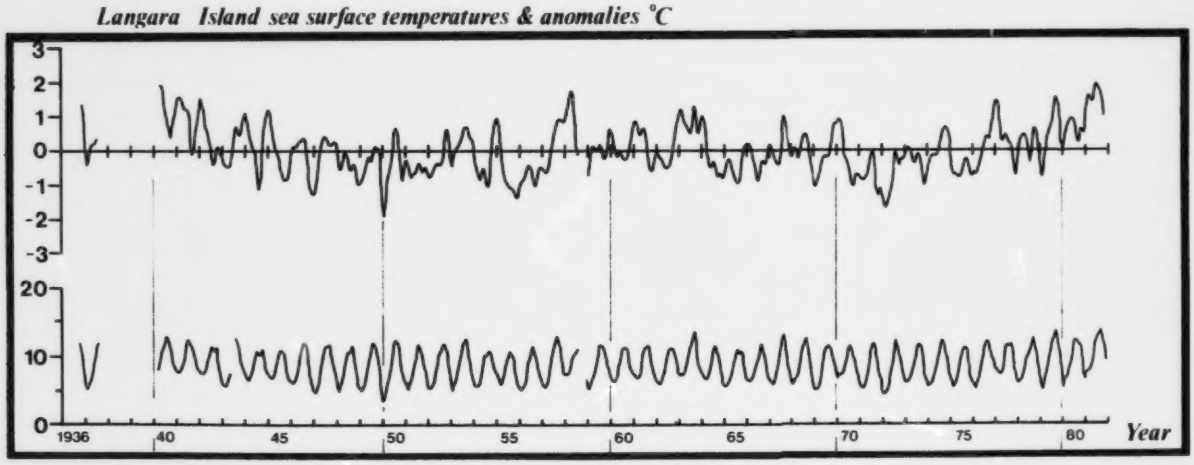
Continental Shelf Studies

The Coastal Ocean Dynamics Experiment (CODE) 3-year field phase ended in June 1981. The overall data recovery from moorings was 93%. The final survey of hydrographic conditions indicated that the low oxygen anomaly was developing once again reflecting 1980 conditions almost exactly despite a substantial difference in the ambient weather conditions.

An overview of the physical oceanography of the southern Vancouver Island continental shelf and a theory of upwellig controlled by the local topography has now been developed. *(Contact: H.J. Freeland.)*

A line of five moorings was deployed along the shelf-edge from southern Vancouver Island to the Queen Charlotte Island in support of an international venture called SUPERCODE. The purpose of the experiment is to search for low frequency disturbances propagating from the tropics along the shelf wave-guide. C.I.C.E.S.E. (Ensenada, Mexico) has deployed moorings off Baja, California and scientists from Oregon State University have deployed moorings along the U.S. coast. Preliminary examination of data indicates substantial coherence between currents off Crescent City (northern California) and off southern Vancouver Island. However, the coherence appears to be largely lost between sites off northern and southern Vancouver Island. *(Contact: H.J. Freeland and D.M. Farmer.)*

Time series of mean monthly sea surface temperature (SST) measured at the Langara Island light station for 45 years, lower plot. The dominant signal is the annual cycle. After removing the annual signal we plot the anomaly of SST, upper plot. The high positive anomaly observed in June 1981 was the largest one measured since observations began in 1936; temperatures reached a maximum of 2.3°C above normal.



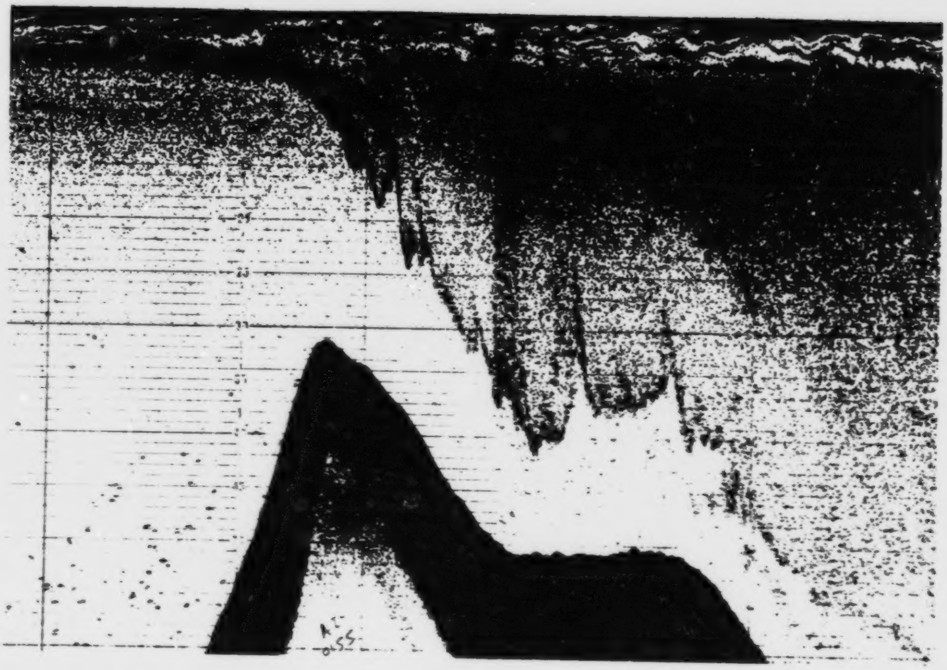
One mooring location is common to CODE and SUPERCODE. This mooring is to be maintained for up to 5 years to acquire some data on the variability of major current systems. For example, a spectacular reversal of the dominant current systems occurs each spring, called the spring transition. The objective is to determine, with 5 or more years of data, whether this is a locally driven event or remotely forced (responding to major changes in weather systems at large distances). Preliminary data indicate that the latter is more likely. *(Contact: H.J. Freeland.)*

Fjord Studies

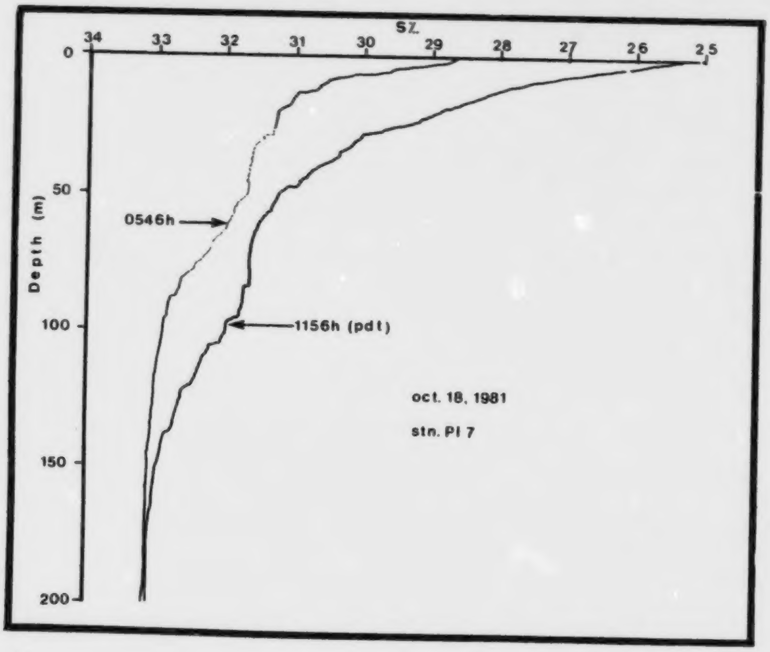
Density data, tide gauge records, anemometer and river discharge data provided a basis for examining the internal pressure field in Knight Inlet. The results emphasized that almost all of the density field adjustment occurs in the top few metres. Significant seasonal fluctuations were observed showing that in summer the main balance of forces in the surface layer was between the horizontal pressure gradient and horizontal stress associated with strong up-inlet winds, with convective accelerations playing a much smaller role than had been supposed. During low run-off periods the horizontal pressure gradient almost disappears, or even changes sign.

Analysis of energetic processes near the sill of Knight Inlet continued by means of a field study combining Aanderaa current meters, automatic current profilers (contributed by Dr. Pond, U.B.C.) and a range-gated Doppler sonar. These measurements have provided a much more detailed data base of documentation than previously available and become the basis for systematic modelling of these flows which occur not only in Knight Inlet, but in many fjords along the coast. *(Contact: D.M. Farmer.)*

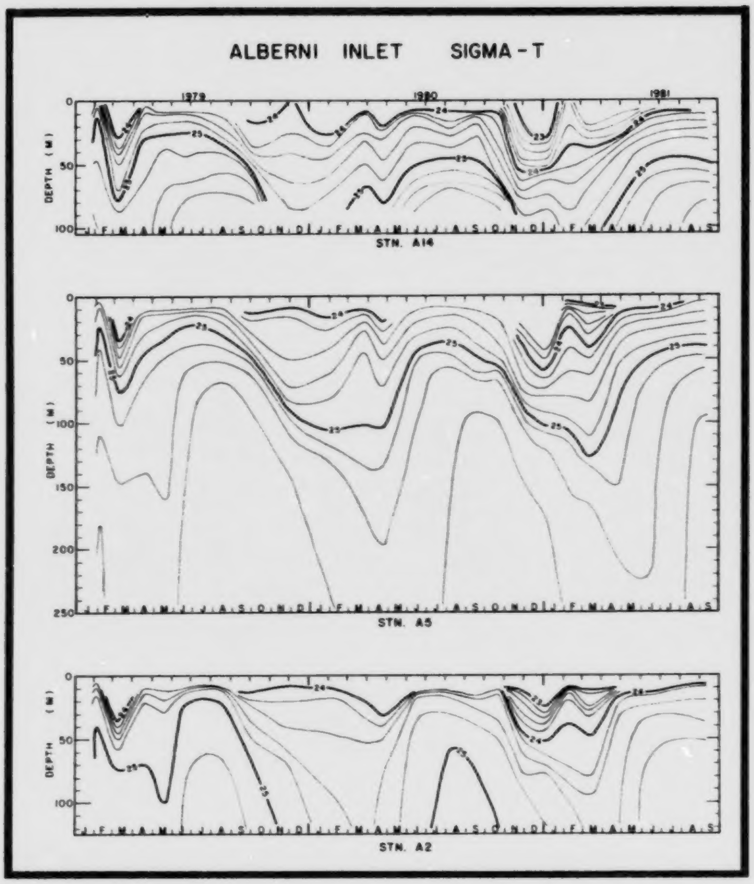
A program to study the circulation of Alice Arm together with the adjacent waters of Observatory Inlet and Hastings Arm was undertaken following expressed concern about the discharge of mine tailings. A second but related effort was directed at monitoring the physical properties, including turbidity, in Alice Arm. Preliminary studies show that flows over submarine sills in the area, which play a prominent part in controlling the circulation, exhibit many of the features previously studied in detail in Knight Inlet. Acoustically-derived images show water moving under the influence of the tide over the crest of the sill in Observatory Inlet, diving down to considerable depths. Salinity and temperature profiles obtained 4 miles east and west of the sill show substantial changes in water properties over a few hours indicating modification of the water down to nearly 200 metres. These energetic processes undoubtedly affect exchanges into Observatory Inlet and Alice Arm. An array of current meters, tide gauges, thermistor chains and



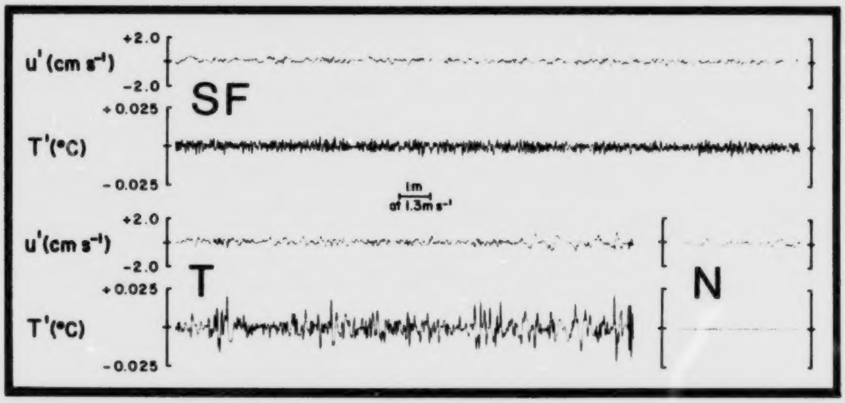
Acoustically derived image showing the Observatory Inlet sill during an ebb tide. The ragged boundary between salty water (below) and brackish water is clearly visible. The brackish layer greatly deepens near the sill and is mixed with the saltier water.



Two profiles of salinity (S$^0/_{00}$) recently obtained 4 nautical miles west of the Observatory Inlet sill near the Nass River, demonstrate the rapid changes that can occur over a few hours through the water column. The changes occur through energetic interaction between tidal currents and the sill which results in the submergence of fresh surface water, partly derived from the Nass, accompanied by intense mixing. The mechanism is illustrated in the acoustic image.



The figure shows specific density anomaly vs time for 3 locations in the Alberni Inlet system. Stn. A2 is in the inner basin, Stn. A5 is in the outer basin, and Stn. A14 is in Barkley Sound. The annual cycle of density changes is readily apparent.



Traces of flucutating temperature T^1 measured by a constant depth system towed east of Hawaii reveal the difference between signatures of two different microscale mixing processes. Salt fingers (SF) are characterized by signals of very limited amplitude and wavelength, which contrast sharply with the much more random fluctuations associated with three-dimensional turbulence (T). A noise level signal (N) is included for comparison.

anemometers have been installed in the area and extensive ship surveys are planned for 1982. *(Contact: D.M. Farmer and D.J. Stucchi.)*

The investigation of some oceanographic features of the Alberni Inlet-Barkley Sound fjord system, and the influence of continental shelf processes on the system continued through 1981. Data analysis is proceeding and a synthesis is emerging. The data confirm that a complete annual replacement of the water in the system occurs with a decrease in dissolved oxygen content, after an initial increase, as dense water flows into the fjord. The data suggest that upwelling processes on the continental shelf supply the low oxygen, high density water allowing renewal of the deep water in the fjord. *(Contact: D.J. Stucchi and W.H. Bell.)*

Acoustic Remote Sensing

The range-gated Doppler sonar under development was tested with a new, narrow beam transducer. Encouraging results were obtained in Knight Inlet, where a number of comparison measurements were taken in a sequence of runs over the sill in conjunction with moored current meter observations. After correction for ship motion, the high flow speeds in the neighbourhood of the sill crest, associated with lee waves and related phenomena, are clearly seen in the velocity maps. The technique promises to be a powerful tool for studying tidal flows and related coastal processes.

Work was begun on development of a correlation sonar for remote measurement of velocity in the ocean. Data were collected with the range-gated Doppler system, reconfigured as a single-channel correlation sonar. Results have provided estimates of the correlation function used in a preliminary analysis of the correlation technique as applied to remote velocity profiling. Another project underway is designed to test the concept of remotely sensing wind-speed through ambient noise measurements in the environment of the continental shelf. *(Contact: D.M. Farmer.)*

Ocean Mixing Processes

Ocean mixing studies have continued with the exploration of the small-scale processes which operate in the ocean. During the year, analysis of towed temperature signals from the subtropical gyre of the north Pacific has revealed signatures which are contrasted with the much more random fluctuations typical of three-dimensional turbulence. Widespread occurrence of salt fingers in subtropical thermoclines has long been hypothesized; now that they have been observed directly, standard theories of ocean mixing must be adapted to allow for the fact that salt fingers, unlike ordinary turbulence, do not transfer heat and salt at the same rate. *(Contact: A. Gargett.)*

Wind Mixing and Restratification

Analysis of temperature observations in Babine Lake confirmed that the depth of wind mixing decreases and that density stratification forms beneath the retreating mixing zone when the stabilizing effect of the cooling below the temperature of maximum density (~ 4°C) dominates, providing estimates of the efficiency of wind mixing under these special conditions. The observations also showed that density gradients increase in the surface boundary flow as the depth of mixing decreases and that the process accelerates in the final stages as the surface buoyancy flux due to cooling is distributed over a progressively thinner layer. *(Contact: D.M. Farmer.)*

Lighthouse Station Program, Task Forces, Mooring Technology

The surface-seawater sampling program at 19 British Columbia shore stations was continued. Pronounced warming of surface waters occurred along the coast in 1981. A large positive sea-surface temperature anomaly, 2.3°C, seen at Langara Island was the largest ever recorded at that site since the program was started in 1936.

Emphasis was placed on the processing and publishing of historical data including those from Bamfield Marine Station and Cape Beale Lighthouse, the West Vancouver Laboratory, and the Vancouver Public Aquarium.

Assistance was provided throughout the year to government departments and the private sector on a variety of environmental problems. *(Contact: L.F. Giovando.)*

A watching brief was continued on developments in mooring technology and related aspects, such as drag and vibration problems. An investigation on the influence of turbulence on drag was initiated. Assistance with mooring design was provided to other groups in the Institute. *(Contact: W.H. Bell.)*

Frozen Sea Research

The objective of the frozen sea research program is to advance the knowledge of the circulation, heat budget and dynamics of the Arctic Ocean and to provide expert information and advice to industry, government agencies and the public.

Eurasian Basin Survey

A survey of the Eurasian Basin known as EUBEX and planned as a cooperative endeavour with the University of Washington, was carried out in a modified form during March and April. The extent of the survey was drastically curtailed by failure to obtain clearance to enter U.S.S.R. airspace east of 32°E and by the loss of the aircraft operated by the University of Washington. Nevertheless an airborne CTD survey covering the area of the ice edge north of Spitsbergen to 85° 30′N and from the Greenwich meridian to 32°E was carried out from Longyerbyen and the FRAM III ice camp. These measurements showed detailed features of the Atlantic water entering the Arctic Ocean and its cooling as it travels along the shelf break north of Spitsbergen. This current is the main source of inflow into the Arctic Ocean and has an effect on the entire basin. Preliminary processing has shown that the data set is of good quality and interpretive work is underway. *(Contact: E.L. Lewis.)*

Deployment of a current-meter mooring from moving sea ice. The mooring winch is on the right, and the ice plug from the mooring hole can be seen to the left of the hanging current meter. The mooring has been "stopped off at the bar lying across the hole to enable insertion of the current meter into the mooring string.

Beaufort Sea Oceanography

An observational program conducted in the Beaufort Sea during March and April included the installation of current meters which were recovered in August. Observations were made west of the U.S. border in cooperation with the U.S. Coast Guard. The entire survey formed part of the second Beaufort Sea Winter Ice Experiment with other components being undertaken by Dome Petroleum and the Atmospheric Environment Service of DOE. CTD sections were taken extending from the deep basin waters to the edge of the landfast ice over a 750 km stretch of coastline. In all, 60 CTD profiles were acquired and seven moorings were deployed and recovered. Measurements verified the presence of a westward current jet overlying the continental slope and demonstrated the existence of a thermohaline front on the outer shelf marking the boundary between waters of the Canadian basin and a mass of saline water at its freezing point, originating from ice formation over the continental shelf. The current meter moorings were situated near this front and those near the sea floor were periodically engulfed by this cold, saline flow. Analysis of these data is proceeding with particular attention being paid to propagation of the front and cross-frontal mixing. *(Contact: H. Melling.)*

Polynya Experiment

Data reduction from the Polynya Experiment is now essentially complete and presentations were made of preliminary analyses at the 1981 Canadian Meteorological and Oceanographic Society (CMOS) meeting and the autumn meeting of the American Geophysical Union (AGU). The measurements of eddy heat flux made within the growing (atmospheric) convective boundary layer show good agreement with existing data taken elsewhere under strongly advective conditions on much larger physical scales. The oceanographic measurements indicate a source of sensible heat in the form of warmer water brought to the surface during high-current periods of the tidal cycle. The existence of the polynya depends on the balance between this oceanic heat source, the surface heat loss, and mechanical removal of ice during periods of high current. *(Contact: E.L. Lewis and R.A. Lake.)*

Northwest Passage

The anticipated year-round use of the Northwest Passage by ice-breaking tankers has stimulated a major research effort in that area. The Working Group on Northwest Passage Oceanography, chaired by IOS, has planned a major field program for the spring of 1982 which has involved a great deal of logistical preparation and instrument testing. Specific projects include: the Channel Flow Experiment (Prince of Wales Strait), the Physical Oceanography of M'Clure Strait and Western Viscount Melville Sound, and a synoptic CTD Survey of the Arctic Channels. The last project will be conducted by contract. These projects are being carried out in association with those of the Canadian Hydrographic Service at both IOS and the Canadian Centre for Inland Waters (CCIW), and with the Barrow Strait Project undertaken by the Physical Oceanographic Group at the Bayfield Laboratory. A complementary survey may be undertaken by Arctic industry in the Northwest Passage and it is intended that data from all these operations will be amalgamated. *(Contact: R.A. Lake.)*

Oil Well Blowout Studies

Work proceeded on deep oil well blowout studies. The results of laboratory measurements on gas hydrate formation in rising gas bubbles have been incorporated into a mathematical model of a complete bubble plume. This should enable calculation of the water depth at which hydrate formation removes completely the buoyancy normally associated with a rising plume of gas bubbles. An international cooperative study concerned with the subsea containment and control of oil well blowouts will be undertaken in 1982 at the Massachusetts Institute of Technology. IOS currently performs an advisory function and will be involved in the field tests. In addition IOS is represented on the management committee of the Arctic Marine Oilspill Programme, chaired by EPS, and on the technical committee for the Cape Hatt Oilspill Experiment. *(Contact: D. Topham.)*

Technical Development

A theoretical analysis of the transient response of a cylindrical conductivity cell was carried out. This enabled development of a computer simulation of the effect of the CTD instrument's response to high conductivity gradients in the sea. The results were expressed in terms of non-dimensional variables which took into account differing lowering rates and cell dimensions. The theory shows good agreement with available experimental results although the latter are few in number.

An airborne CTD survey system suitable for use in Twin Otter aircraft was developed for the EUBEX and Beaufort Sea surveys. It has proven very successful Also developed was a CTD system designed for use from a Bell Model 206 or equivalent helicopter with the lightweight winch carrying only 500 m of cable. It will be utilized in the spring of 1982 in the Northweast Passage. Work was begun on the design of Mark II of the "salinity sucker," a device for measuring ice crystal content and super cooling in seawater. The device pumps seawater through a filter *in situ* and melts the collected ice. Mark II will be a "clip on" addition to the standard Guildline CTD unit commonly in use which would enable immediate experimental analysis of peculiar field observations. All these CTD systems or devices have benefitted greatly from the analysis of the design of CTD experimental programs carried out in 1980 and by studies of the transient response of conductivity cells during 1981.

A "hole melter" was designed for cutting large holes in sheets of sea ice. The principle followed that developed by the Applied Physics

Laboratory at the University of Washington. By pumping hot water from a diesel-fired boiler into a copper pipe frame which was bent to the shape of the periphery of the desired hole, a 4 kW source of heat cut an annulus of 30 cm mean radius and 10 cm thickness through 2 m of sea ice in 30 minutes. This size of hole is desirable for deployment of a current meter chain. The associated winch gear for handling loads of up to 10 kg was developed simultaneously.

The Practical Salinity Scale, 1978, has now been officially adopted by IAPSO, ICES and SCOR (International Association of Physical Science for the Oceans, International Council for Exploration of the Seas and Scientific Committee on Oceanic Research) and will be used for reporting oceanographic data. Tables of the new scale were produced for publication for UNESCO.

The group interfaced a Guildline CTD system with a transmissiometer for monitoring water quality in Alice Arm, and also supplied scientific and technical manpower to this program.

Offshore Oceanography

Offshore oceanographic studies focus on the distribution of ocean properties and currents and the processes controlling them. This includes air-sea interaction, detection of the propagation of disturbances, and the relationship between open ocean and coastal processes.

Ocean Climate Monitoring Studies

With the withdrawal of the weatherships from service in 1981, a long time-series of ocean measurements taken from these vessels at Station P and Line P came to an end. These observations very possibly constitute the longest time-series measurements in the open ocean. Such data are considered by various international agencies and most oceanographers active in climate study to be one of the most important oceanic time-series having relevance to the study of the impact of the ocean to climate.

IOS initiated a follow-on program of observations of two-weeks duration along Line P and at Station P every two months. During the oceanographic research vessel cruises in August and October, the Canadian Wildlife Service examined marine birds and several sattelite-tracked drifting buoys were released near Station P on behalf of he U.S. National Centre for Atmospheric Research (NCAR). *(Contact: S. Tabata.)*

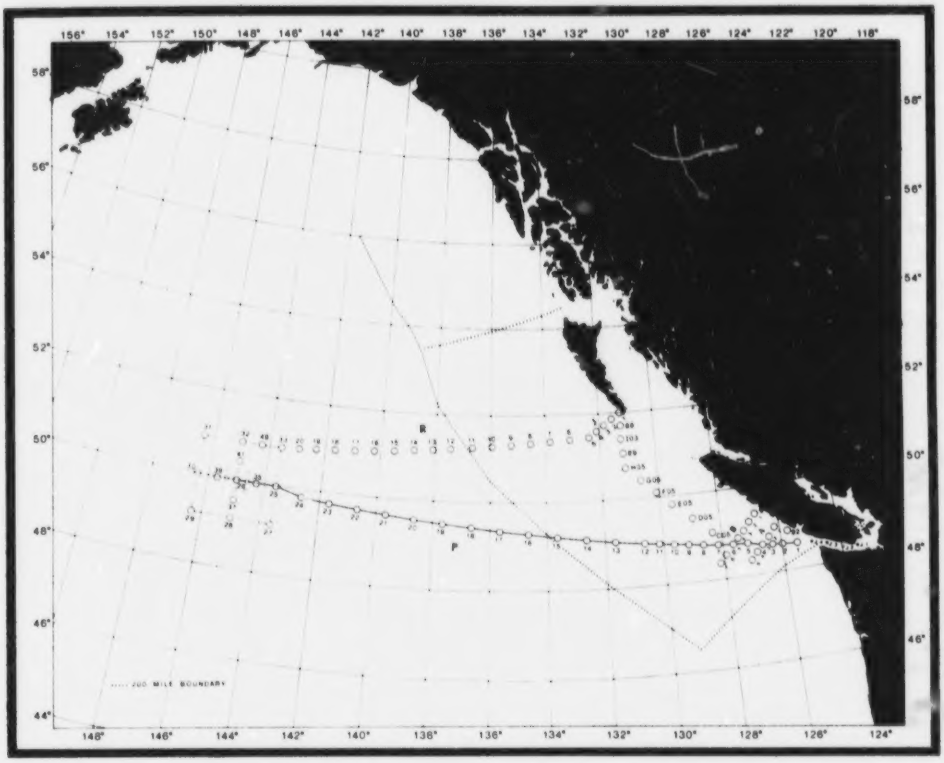
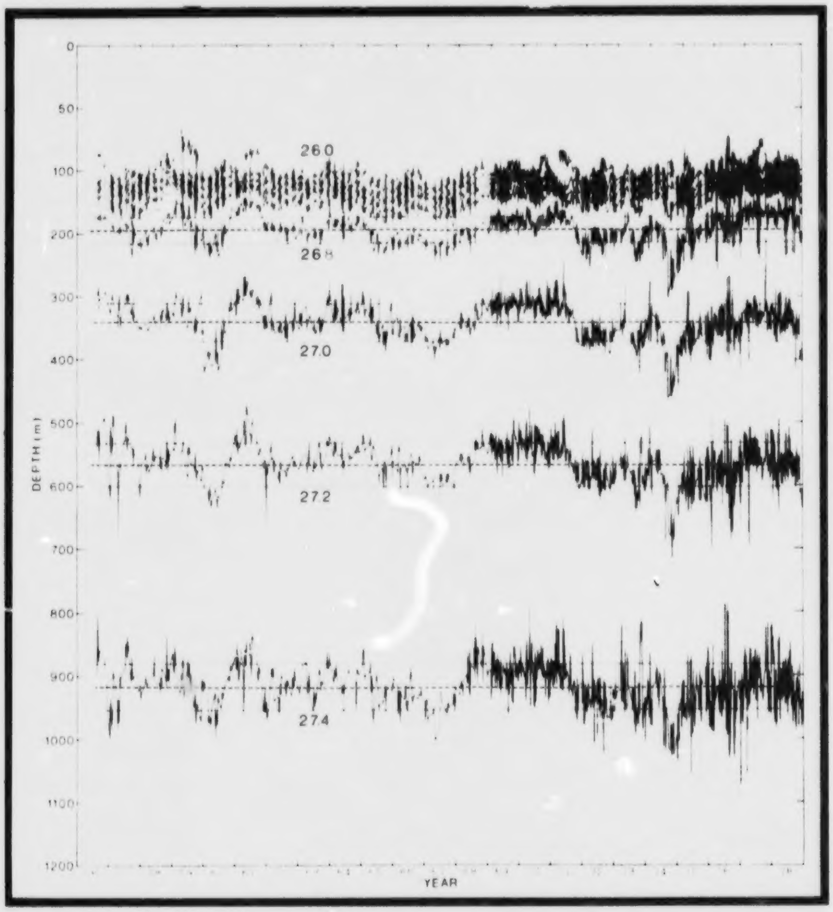


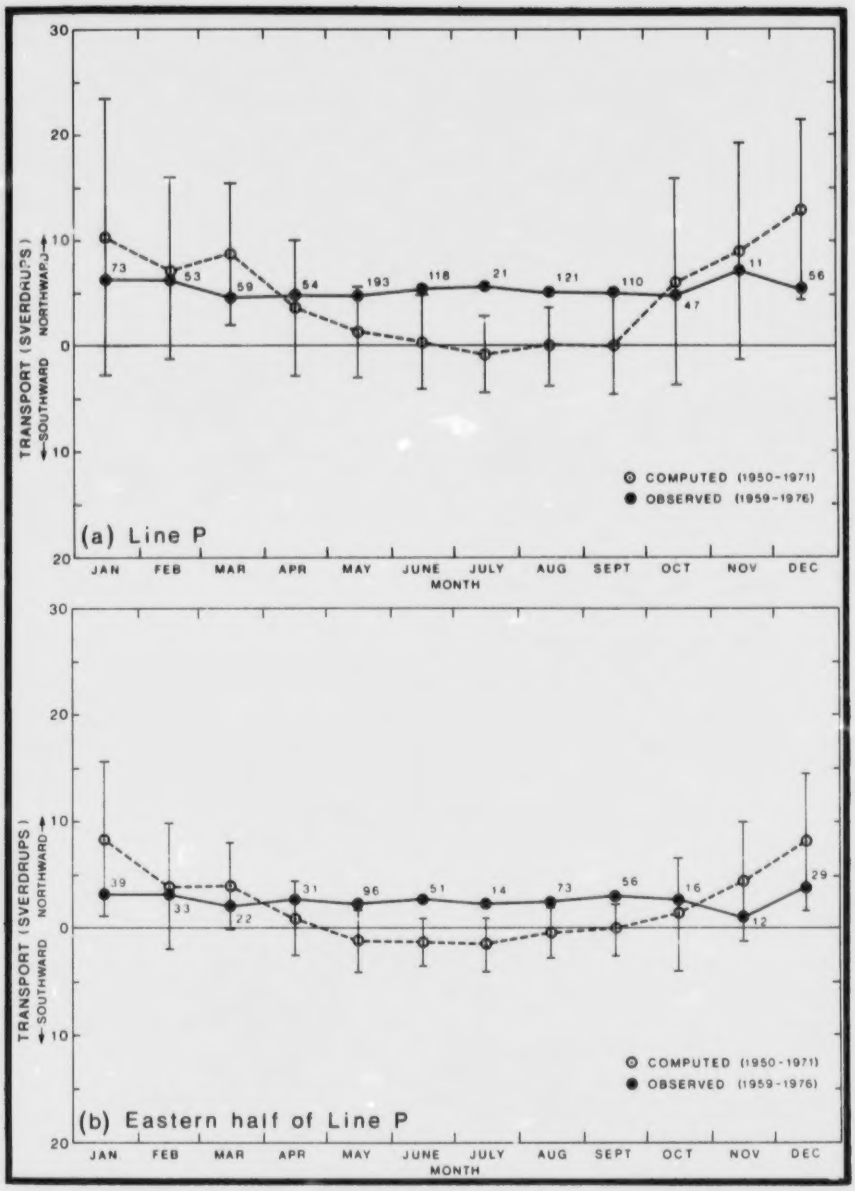
Chart showing positions of stations scheduled for observations during Ocean Climate Monitoring Surveys. Observations along Line P and Station P are taken during the outbound trip. The return trip may be via north or south of the Line. At present it consists of observations via the offing of southern Queen Charlotte Island. A line of stations perpendicular to the west coast of Vancouver Island is included to provide supporting data useful for the examination of detailed oceanographic changes along the continental slope.

Results of Station P Data

Twenty years of oceanographic observations at Station P was examined revealing that beneath the seasonally-influenced upper layers of the ocean, well-defined, long-term fluctuations of oceanographic properties occur. These are more distinct and persistent than the climatic anomalies evident in the sea-surface temperatures. For example, at 200 metres, the water was relatively warm during 1956-60, with maximum temperature occurring in 1960; cool during the years 1961-71, with minimum temperature in 1965; and warm during 1972-76, with a maximum temperature in 1974. In general, the presence of warm water was associated with higher salinity and cool water with less salinity. Although there were instances when the presence of low oxygen (oxyty) water correlated with the warm water, there were occasions when the opposite occurred. Most of these water property changes at standard depths can be attributed to the effects of advection while part is explained by the long-term vertical motion of water. However, a much longer series of data is needed to determine if the long-term fluctuations have discernible periodicity. *(Contact: S. Tabata.)*



The depths of the isopycnal surfaces in the halocline and below do not possess any discernable annual cycle but their variability is dominated by large, long-period fluctuations. Their ranges are largest for higher values of σ_t *(27.0-27.4) reaching almost 200 m and are smallest in the halocline. Their variability could not be readily related to results of any known theories of ocean circulation. Significant changes of temperature, salinity and oxyty at isobaric surfaces are related to the vertical changes of these depth for 1959 and 1961.*



Observed (relative to 1000-decibar surface) and computed baroclinic transport (sverdrups) across Line P (a) and eastern half of Line P (b). The observed values are based on distribution of potential energy along the line while the computed values are based on estimates made by Bakun (private communication) using Sverdrup's model. The standard deviation associated with the observed values are typically ± 0.2 sverdrup. (Numeral denotes number of stations used to estimate observed transport. Φ denotes standard deviation associated with computed transport.)

Coastal Ocean Dynamics Experiment (CODE)

The purpose of CODE was to provide detailed information on the spatial and temporal variability of currents, winds, sea levels and water properties off the west coast of Vancouver Island. Instrument deployment covered the period from May 1979 to September 1980.

Observations have revealed the presence of strong (10 cm/s) continental shelf wave motions of diurnal period which give rise to predominantly diurnal currrents over the shelf and slope region of the Vancouver Island coast. These data provide the most convincing and comprehensive proof to data of the existence of continental shelf waves. Wavelengths are in the range 200-400 km and effects of stratification appear to be significant. A theory has been formulated to account for the generation of these waves through a time-dependent, turbulent bottom boundary layer associated with tidal currents over the shelf-slope region.

Preliminary analysis of the CODE data further reveals that wind-generated, near-inertial, internal gravity waves propagate to depths exceeding 1500 m in offshore regions but appear to be confined to near-surface depths over the shelf. There is also evidence for strong M_2 baroclinic tides seaward of the Vancouver Island shelf. Low-frequency currents, with periods of 20-60 days, have speeds in the range of 0.1-1 cm/s throughout the upper 2000 m and show considerable non-seasonable variability. Results further suggest the existence of a persistent northward baroclinic current adjacent to the coast of central Vancouver Island. Dynamic height contours reveal convoluted circulation patterns off the coast with numerous well-defined mesoscale eddies. *(Contact: R.E. Thomson.)*

Queen Charlotte Sound — Hecate Strait

Analysis has been completed on much of the wind, current and water property data collected jointly with Tides and Currents section from May-September 1977 in the Queen Charlotte Sound — Hecate Strait region. Two publications deal with the strong (50 cm/s), persistent (10 days) and highly spatially-coherent, wind-generated, inertial oscillations within the seaway. Reports were completed on the currents and water properties at all locations and a summary report on aspects of the physical oceanography of the region has been initiated.

An analysis was also completed of Ekman current meter records collected in 1954 and 1955 in Queen Charlotte Sound, Hecate Strait and Dixon Entrance. Currents were predominantly of semidiurnal period and showed appreciable vertical structure at all major tidal frequencies. *(Contact: R.E. Thomson.)*

Book on Oceanography

A book entitled *Oceanography of the British Columbia Coast* was published by the Scientific Information and Publications Branch in November 1981. Consisting of 291 pages, over 300 diagrams and 13 colour plates, the book deals with the physical aspects of the sea as exemplified by the Pacific Ocean and the contiguous waters of the British Columbia coast. *(Contact: R.E. Thomson.)*

Sea Levels in Eastern Pacific Ocean

Mean monthly sea level heights, pressures, temperatures and salinities from 16 coastal stations from southern California to the Aleutian Islands were analyzed. In addition to the pronounced annual cycle in these data, there is a significant peak centred at 5.7 years in the pressure-corrected sea level height. This signal is coherent along the entire coast and has an average northward propagation speed of 25-30 cm/s indicative of a long barotropic or baroclinic, coastally-trapped wave.

The data further show that sea level responses to atmospheric pressure fluctuations typically exceed the standard inverse barometer effect of 1.01 cm/mb. Greatest "effective" barometric correction factors are off the coasts of Washington and British Columbia where values can exceed 2.0 cm/mb; minimum values are off northern California and are less than 1.0 cm/mb. Other major features of the sea level data include significant trends: earthquake rebound times of about 10 years, pronounced barometric responses at mid-latitudes and marked correlations with sea surface temperature anomalies at low latitudes. Salinity related steric effects are shown to be important off Vancouver Island. *(Contact: R.E. Thomson and S. Tabata.)*

Seiches in Juan de Fuca Strait

In September, high resolution pressure gauges were set in Becher Bay and Port San Juan by the Tides and Currents section to detect intermittent seiche activity believed to originate from edge-wave excitation. These data together with similar data collected in 1978 and 1980 are being analysed to determine phase speeds and structure of the edge-wave motions. Stilling-Well tide gauge records for Victoria and Esquimalt harbours are also being digitized for use in interpreting such motions. *(Contact: R.E. Thomson.)*

Numerical Modelling

The Numerical Modelling section is involved in development and application of numerical methods in support of a wide variety of observational and theoretical research programs sponsored by the Institute of Ocean Sciences and other agencies. Numerical models are used in the planning and interpretation of field programs, in the design of pollution and inundation countermeasures by the simulation of hypothetical worst-case scenarios, and in the clarification of mathematical theories of wave physics by numerical evaluation of test cases.

Xia Zhong Wan, an exchange scientist from the First Institute of Oceanography, Qingdao, China, spent seven months of his two-year stay at IOS involved in programming and testing a model of the Yellow Sea.

Software for automated set-up of explicit, finite-difference models of tidal, storm surge and tsunami effects in coastal seas was developed and written up during 1981, resulting in very substantial reduction of programming and debugging time for project programmers. *(Contact: R.F. Henry.)*

Two projects have defined the requirements for further observational programs. Simulation of internal Kelvin waves in Knight Inlet revealed possible ambiguities in the interpretation of current meter records. Modelling of tides in M'Clure Strait and Viscount Melville Sound, carried out in conjunction with L. Ku (CHS, Ottawa), confirmed that certain suspected anomalies in existing records are serious enough to justify further field studies. *(Contact: R.F. Henry.)*

Storm surge and tidal modelling studies of the Bay of Bengal, undertaken on behalf of W.M.O., resulted in a proposal for a follow-up international water-level measurement project in this area. *(Contact: R.F. Henry and T.S. Murty.)*

Working jointly with Dr. G.A. McBean of the Atmospheric Environment Service, preliminary studies of explosive cyclogenesis over the north-east Pacific Ocean were carried out. Using meterological data covering a 23-year period, correlations between the rate of deepening of extratropical cyclones and sea surface temperatures and potential layer depths were computed. Also,using concepts of tsunami magnitude developed jointly with Dr. H.G. Loomis (University of Hawaii), an understanding of the energy transfer from earthquakes to tsunamis was advanced. *(Contact: T.S. Murty.)*

Aspects of the density-driven circulation in the Georgia-Fuca system continued to be studied with the aid of the GF4 and GF5 laterally-integrated models and three-dimensional models (GF6) of the overall system.

Discharge from the Fraser River, which undergoes strong tidal and seasonal modulation, forms a shallow brackish layer over the deep, denser water in strongly tidal southern Strait of Georgia. A field program has been initiated with Beak Consultants Ltd. to extend and verify earlier collaborative modelling with Dr. J. Stronach on the development of a numerical model (GF4), in which layer thickness and the vertically-averaged layer densities and velocities are computed. Initial results indicate that the basic features of the circulation, in the absence of significant winds, involve a splitting of the emergent stream from the river against the shores of the Gulf Islands opposite. The northerly component contributes to a large clockwise gyre extending over the full width of the Strait while the southerly component moves towards the strong tidal mixing region of the San Juan Islands.

Numerical studies of large-scale, seasonal, density-driven circulation involved sensitivity trials to evaluate the capacity of the models to simulate observed changes in overall scalar distributuion. Understanding the relation between the diffusive properties of a scheme and the mesh spacing, in particular with relation to scales encountered on the B.C. coast, is being approached on two major different scales.

On the smaller scale, the laterally-integrated numerical scheme applied in the GF5 format is being used to construct a model of the Burrard Inlet system. This is a collaborative project with Professor R.W. Burling and D. Dunbar of the University of British Columbia.

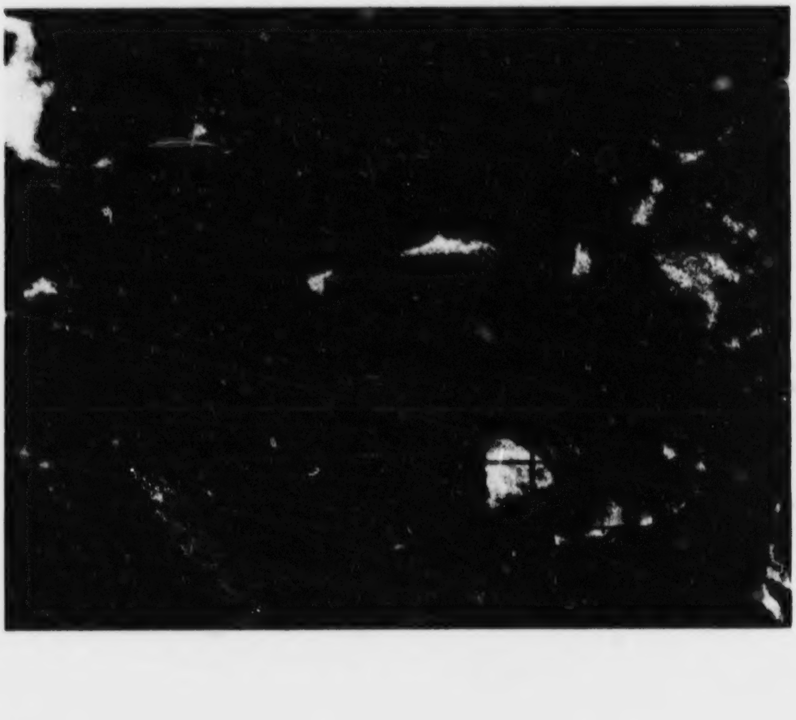
On the larger scale, extensive analyses have beeen carried out on results obtained from trials of the three-dimensional, seven-level model GF6 in a collaborative project with Dr. J. Backhaus of the University of Hamburg. A feature of these results concerns potentially important interactions between the overall density-driven circulation and strong local tidal residual circulation. Notable shortcomings of the model in connection with the latter phenomenon have necessitated redesign and calibration to accommodate barotropic mixed tidal simulation.
(Contact: P.B. Crean.)

In addition, a method of calculating continental shelf wave profiles and dispersion curves was developed and tested and a study was started on the optimal choice of a finite element method of solving the linearized shallow water equations.

Remote Sensing

The Remote Sensing group at the Institute of Ocean Sciences continued to concentrate its attention on the remote mapping of ocean colour (spectral reflectance) for deducing the surface distribution of chlorophyll-a. This type of work is now being undertaken by numerous groups around the world, but for the most part using only the absorption of blue light by chlorophyll pigments as the means of detection. At IOS, research has led to airborne sensing of natural chlorophyll fluorencence and most recently the investigation of this technique for space application.

An evaluation of this possibility by a consortium of university and industrial groups managed by the Canadian Corporation for University Space Science (CCUSS) has concluded that a suitable sensor could indeed be built and that such work would be a logical and timely extension of developments now being undertaken by Canadian companies. Further studies and construction of a prototype sensor will be undertaken jointly with the Interdepartmental Committee on Space and the Department of Fisheries and Oceans.



Satellite image of an area of the Atlantic Ocean 150 km across showing the surface colouration caused by an extensive plankton bloom south of Iceland on June 19, 1976. The three areas shown have been used to study the spatial properties of two-dimensional turbulence, as described in a recent paper by Gower, Denman and Holyer in the journal "Nature."

Additional studies included analysis of zenith sky spectra demonstrating the complexity of effects that might be encountered through the atmosphere. Data collected at IOS show that atmospheric variation effects should be manageable, but the full range of flexibility and sensitivity of the proposed sensor will certainly be needed. Studies have also been made of chlorophyll fluorescence in B.C. coastal waters. These related especially to the variation of fluorescence efficiency in natural phytoplankton populations.

The international symposium "Oceanography from Space," organized for COSPAR, SCOR, and the IUCRM (Committee on Space Research, Scientific Committee on Oceanic Research and the Inter-Union Commission on Radio Meteorology) in Venice, Italy, attracted about 200 attendees from many countries. The proceedings, Volume 13 of the Plenum Press Marine Science series, contains summaries of the state of the art in different techniques of satellite remote sensing of the oceans.

Other projects during 1981 included: development of an improved multi-channel spectrometer for airborne work, development of software for analysis of satellite imagery, and participation in both NASA's water colour working group and the Canadian Radarsat oceans team. *(Contact: J. Gower.)*

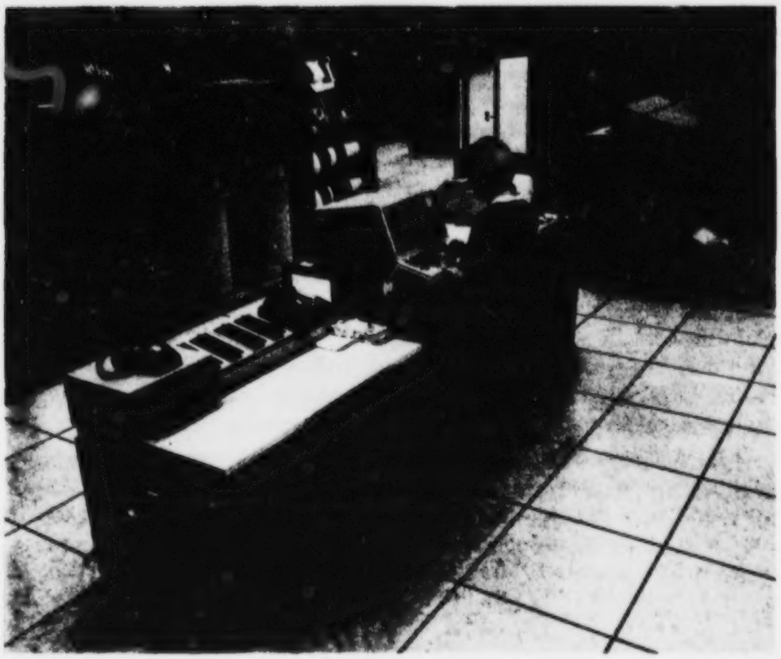
Computing Services

With only a total system down-time of just over two weeks, the old Univac 1106 computer was replaced with a compatible 1100/60 system, with no conversion of user programs or data files being required. The new system includes: 1100/61 Model C1 Central Processing Unit (CPU), 524 K 36-bit words of memory and a Houston DP8S3 incremental plotter.

A floating point systems AP-190L array processor (128 K words) was acquired in March for use primarily in support of numerical modelling studies.

Other improvements included implementation of new plotting hardware (a large on-line Houston plotter) with supporting software. A new level of the Univac operating system (36R2D) and libraries were also installed with the 1100/60. Comparisons indicated that the average cost of runs on the new system was 70% of the cost of those on the previous system while providing nearly 3 times the main memory, 4 times the mass storage, and improved turn-around time.

Development in the area of small computers continued in 1981



Univac 1100/60 Computer System. Systems Support Processor and Operator's Console are in foreground. The Array Processor is the light-coloured box in right background. The 1100/60 CPU and Memory are immediately behind the Array Processor.

through upgrading and acquisitions such as the PDP-11/34 for field hydrography. A year-end survey of small computers used for both oceanographic and hydrographic work, showed 16 mini-computer based systems, 7 large programmable calculator systems, various microprocessor based data acquisition systems, 16 personal computers and over 40 terminals in use with the central computer.

Extensive changes and additions were also made to the automated cartography software. These included: modifications to accommodate the new plotting table, implementation of new versions of GOMADS (Graphic On-line Interactive Editing and Compilation System), and the RSX11M operating system, the addition of a new symbol disc with supporting software for the Kongsberg photoplotter, and implementation of the Digital Data Library (DDL) software on the Univac system.

Ocean Chemistry

The major objective of the Ocean Chemistry Division is to provide expertise, advice and a reasonable scientific perspective on both short- and long-term problems associated with the chemical aspects of the ocean environment.

Five areas are of prime concern: ocean pollution, ocean climate, ocean fluxes, ocean circulation and ocean productivity. A balance must be struck between study of the short-term impacts of societal intrusion and the longer-term consequences to the environment.

The *Hudson* 81 circumnavigation cruise provided the opportunity for a month-long study of upwelling areas between Costa Rica and Victoria, B.C. Carbon dioxide (CO_2) and trace metal studies were conducted in the deep-sea trenches off Mexico and central America, over geothermal vents in the East Pacific Rise and in the anoxic basins off southern California.

Enclosed Ocean Experiments

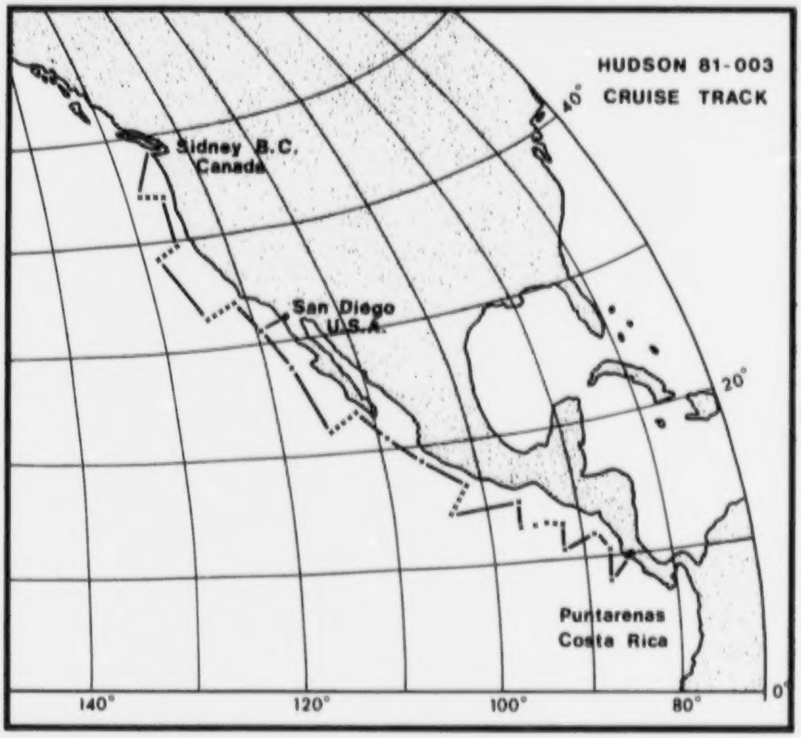
1981 was the second year of the SEAFLUXES (sediment/ecosystem/atmosphere flux enclosure study) program to research pathways, budgets and processes of pollutants and natural compounds in the marine environment. Medium-scale enclosures of sea water and plankton (60,000 - 1,000,000 litres range) in Patricia Bay, B.C. were utilized to sustain a marine ecosystem for experimental studies.

Three experiments were conducted using the controlled-environment, CEPEX-type enclosures. The major one invovled a copper-glucose experiment in cooperation with Dr. H. Seki of the University of Tsukuba, Japan. The effect of a simultaneous addition of 4 mg of glucose with 8 μg copper (Cu) per litre of sea water was measured by uptake rates of organic substrates of microorganisms. Drastic reduction of higher trophic levels was observed, in sharp contrast to the effect of just Cu addition without glucose leading to diatom bloom through reduction of grazing pressure. The addition of Cu only was also found to produce increasing sedimentation of organic matter and faster depletion of nitrate in the ecosystem. The second project, undertaken cooperatively with Dr. Handa of Nagoya University and Drs. Takahashi and Ichimura of the University of Tsukuba, studied metabolite production using isotyopes of ^{15}N and ^{14}C to trace uptake of ammonia, nitrate and CO_2 by different phytoplankton populations. The third experiment was conducted jointly with Dr. B. Imber of Southampton University and Dr. M. Robinson of Royal Roads Military College to study the metal binding ability of organics associated with heavy growth of single species cultures.

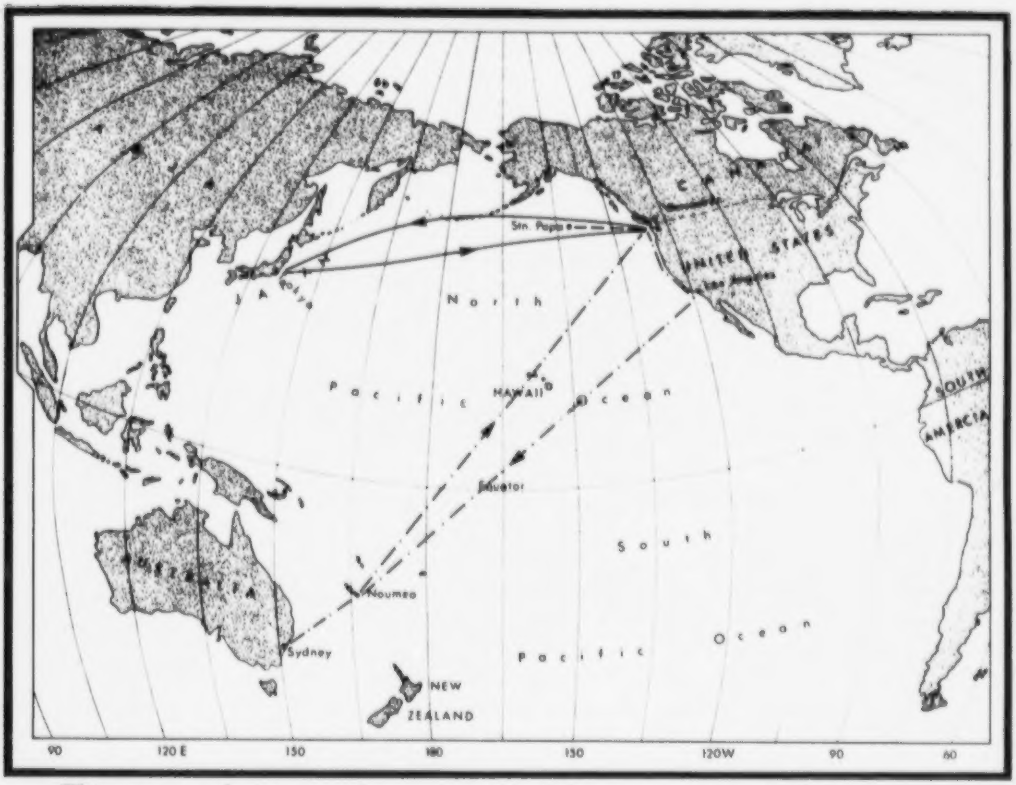
The CHEMCELL sediment/sea water experimental system was attached to the seabottom at Patricia Bay to study its performance characteristics. Dr. F. Pollehne from the Institut für Meereskunde at Kiel, F.R. Germany, contributed to a study of nutrient regeneration using sediments obtained near the site and the rates of fecal pellet and phytoplankton regeneration processes in contact with sediments. *(Contact: C.S. Wong.)*

Marine Carbon Research Centre

The Ocean Science and Surveys Marine Carbon Research Centre at IOS, now in its third year, is focussing on the marine aspects of the global CO_2 cycle. In recent years the scientific community has expressed increasing concern over global warming, especially as evidenced by a continuing warming trend of Antarctic air temperature. There is a new sense of urgency in understanding the mechanism of the global carbon cycle which determines the time-scale of the "greenhouse effect" of CO_2. It is particularly important to study the role of the ocean, representing the major sink of atmospheric CO_2, in the cycle.



Cruise track of the CSS Hudson in the tropical Pacific Ocean; the cruise was used for CO_2, trace metals and chemical oceanography studies.



The routes of the Canada Ace and the Lillooet, the ships-of-opportunity engaged in CO_2 monitoring in the Pacific Ocean.

This program has two main components: CO_2 monitoring and CO_2 research. CO_2 monitoring is an esential tool in establishing the first signals of oceanic CO_2 increase, the secular increase, and long-term variability. The ocean CO_2 monitoring program is being developed using three types of platforms: ships of opportunity, research ships along Line P, and B.C. lighthouses. Two ships of opportunity are being used: the *Canada Ace* between Nagoya, Japan and Richmond, B..C. with 16 crossings a year in the north Pacific Drift and Subarctic waters, and the *Lillooet,* between Sydney, Australia, and Vancouver, B.C. making 12 crossing a year over the South Pacific Gyre, the Equatorial waters, the North Pacific Central Gyre and the southern edge of Sububarctic waters. Such CO_2 time-series will contribute substantially to the data base for CO_2 research and predictive modelling.

CO_2 research in 1981 was highlighted by a study of the marine carbon cycle in the East Boundary waters off the west coast of the North American continent undertaken as part of the *Hudson* expedition. The studies were multi-faceted involving joint participation from IOS, the Bedford Institute of Oceanography, U.B.C.'s Department of

Oceanography, and the Department of Geology at Dalhousie University. Measurements of atmospheric and oceanic CO_2 content, particulate and dissovled organic carbon, alkalinity, nutrients, chlorophyll-a and other supporting oceanographic parameters were made in the coastal waters off Central America, Mexico, California and Oregon. These areas contain upwelling waters which are CO_2 rich.

One of the objectives of the work was to understand the air-CO_2 transfer where deeper waters were brought into contact with the atmosphere. Preliminary data indicate that during the cruise period (April 9 - May 9), the ocean appeared to be absorbing CO_2 from the atmosphere except in the extreme nearshore upwelling areas. In these locations pCO_2 (the partial pressure of CO_2 in sea water) can exceed present atmospheric CO_2 levels of about 345 ppm by as much as 100 ppm *(Contact: C.S. Wong.)*

Hydrocarbons and Pesticides

The objective of the program is to advance the knowledge of the occurrence, pathways and fate of hydrocarbons (natural, petroleum-based, chlorinated and pesticides) in the marine environment.

PAHs (polycyclic aromatic hydrocarbons) belong to a class of organic compounds that may induce undesirable biological effects. A histological survey of the blue mussel *(Mytilus edulis)* was conducted in Kitimat Harbour and approaches and in Alberni Inlet. In mussel samples collected in 1980 and 1981, abnormal physiological conditions similar to those observed in 1979 samples were absent. A similar histological and chemical survey of the same mussel species was conducted in selected southern Vancouver Island waters. Two types of neoplasms were detected, 12% of which were identified as hemopeietic neoplasm. This prevalence, in agreement with that for mussels in several U.S. bays, is the first reported in Canadian waters. Mussels from Cowichan Bay showed 4% incidence of a gonadal neoplasm, not previously observed in mussels, although documented in soft shell clams from the northeast coast of the United States.

A chemical method has been developed to isolate PAHs and other organics from biological tissues of marine organisms. Constituents can now be isolated in sufficient quantity without loss of chemical integrity for use in short-term bioassays of chemical carcinogens and mutagens. A contaminant-free freeze-dryer was designed to reduce the bulk of biological tissues to a smaller weight by removing 90% of the tissue water.

Participation in the Baffin Island Oil Spill (BIOS) project was mainly advisory: serving as scientific authority and chairman of the Chemical Sub-committee on the chemical fate and effect study. The objective of the project is to compare the impact of undispersed and chemically-dispersed crude oil in Arctic coastal ecosystems. In the summer, a trial study of the equipment to inject the oil and dispersant, operating procedures and strategy of coordinating personnel and vessels was carried out in Saanichton Bay, B.C. *(Contact: W.J. Cretney.)*

Trace Metals in Sea Water

The objective of the trace metals program is to assess the distribution and fluxes of natural and man-mobilized metals in the ocean, especailly their interactions with suspended matter, the planktonic biota and surface sediments.

A major international symposium on "Trace Metals in Sea Water," funded by both NATO and the U.S. Office of Naval Research, was held in Erice, Italy with seventy invited experts, mostly from NATO countries, to summarize the state of the art of the subject. The main theme centred on determination of accurate levels of trace metals in sea water, especially those established by contaminant-free precautions, and on the implications of such realistic but extremely low levels on biological effect studies and on chemical speciation modelling. *(Contact: C.S. Wong.)*

The *Hudson* cruise provided an opportunity to study the distribution of metals in open-ocean waters in the tropical Pacific Ocean and in upwelled waters off the North American coast. A profile of contaminant-free samples was collected over the geothermal vent on the East Pacific Rise, using the Patterson-Schaule sampler for lead and mercury. Preliminary data showed that mercury levels were extremely low, averaging 5 ng L^{-1} in the open ocean and being invariant with depth. In the productive upwelled waters, the lowest value was 3 ng L^{-1}. It is possible that organic production removes metals quickly from the surface mixed layer via a detritus flux to the sediment. Similarly, the lowest lead level ever reported, 2 ng L^{-1}, was detected by isotope dilution method in the coastal fjord waters in Alice Arm, B.C. These extremely low concentrations of lead and mercury in sea water illustrate the extraordinary assimilative capacity of the ocean. *(Contact: C.S. Wong.)*

A NATO-funded program to develop "standard sea water" having trace metals concentrations approximating natural levels is near completion. A long-term storage study on lead, mercury, cadmium, zinc, copper, nickel, cobalt and iron in sea water over a period of almost a year has indicated the feasibility of storing some metals without changes over a long time. Certification of the NATO standard will be a joint effort of Ocean Chemistry Division of IOS and the Jülich Nuclear Research Institute of F.R. Germany under the direction of Professor Nürnberg. *(Contact: C.S. Wong.)*

A joint Canada/F.R. Germany experiment with Dr. Balzer of Kiel University was carried out in August using the German belljar system over sediment at the Kiel Bight to study the chemical speciation of chromium. Preliminary results indicated a rapid reduction of Cr(III) to Cr(II) in the sediment but no migration of CR(III) out of the sediment was detected. *(Contact: R.W. Macdonald.)*

Arctic and Fjord Chemistry

The objective of the program is to gain new knowledge of the environmental factors controlling the circulation and sedimentation in B.C. fjords and in the Arctic. Such new knowledge will contribute to environmental impact statements and assessment of pollutant effects associated with development of the western Arctic for oil and gas, and with industrial activity in coastal inlets of B.C.

The Kitimat fjord system has received attention because of potential oil port development, a proposed methanol factory, and the development of heavy industry in the area. A joint cruise with Ocean Ecology Division and the Pacific Geoscience Centre was conducted to measure the total loading of particulates above the pycocline for the upper reaches of the Kitimat fjord system and to collect sediment cores for lead-210 dating.

Activities concerning the Arctic were mainly limited to summarizing past data jointly with Ocean Information Division. A physical and chemical mass balance study examined metal fluxes and residence times for the southern Beaufort Sea. A study of heavy metals in barites, a material used in drilling fluids, suggested that metal inputs were not significant from drilling operations except possibly in close proximity to well sites. The metals, generally as sulphide inclusions, are not bioavailable unless oxidized. *(Contact: R.W. Macdonald.)*

Coastal Pollution

To increase the level of knowledge concerning the effects of mine tailings disposal, IOS embarked on an 18-month research program to study chemical aspects of the mine tailings disposal operation in Alice Arm, B.C.

The chemistry component covers three areas: sediment-pore water interactions; a time-series study of natural river inputs and mine tailings settling; and water column chemistry. Lead isotopes were used to trace the origin and pathways of lead derived from tailings entering the fjord. *(Contact: C.S. Wong, R.W. Macdonald, J.A.J. Thompson.)*

A joint study was conducted with Royal Roads Military College to establish the relative importance of arsenic (As) in mine tailings to overall budget of this metal in Rupert Inlet and adjoining waters. Sea water and sediment samples were collected and analysed for inorganic As(III)/As(V) and organioarsenic species. *(Contact: J.A.J. Thomspon.)*

De-toxification mechanisms operating within marine organisms are important in the asessment of pollutant effects. Metallothonein, a metal-binding protein, has been the subject of cooperative work with Dr. R. Cosson, on a France/Canada Exchange Fellowship. Substantial improvement has been achieved in refining the differential pulse polarography technique to detect metallothionein at a much lower limit of 17 nanomoles, by using a thermostatted cell at 17°C. This procedure was successfully applied to the assay of protein in shellfish. *(Contact: J.A.J. Thompson.)*

Ocean Ecology

The ocean ecology program is aimed at increased understanding of the factors responsible for the distribution, production, growth rate and behaviour of marine plankton and the biological and physical factors responsible for the distribution of benthic organisms. These find application in resource extraction and management, and waste disposal into the sea.

Plankton

Two cruises in April and Sepember 1981 concluded a four year study of the planktonic ecosystem off the southwest coast of Vancouver Island. Sampling of the benthos beneath the study area was undertaken by contract to determine if any detectable relationship exists between it and the ambient plankton production. The enhanced primary productivity generated over the southern shelf region that lasts throughout the summer months, appears to result from nutrient-rich waters flowing up the Juan de Fuca submarine canyon in response to pressure gradients caused by a near surface counter-clockwise current eddy.

Statistical analysis methods originally developed in geography/numerical taxonomy have been adapted to allow ecological studies of the coherence scale and geographic pattern of plankton community structure on the continental shelf. Various aspects of the work have been prepared for publication and have been presented at scientific meetings. Discussions with American colleagues from the Pacific Coast states may lead to future cooperative work. Collaboration with NASA is already enabling comparison of satellite imagery with IOS field work. *(Contact: K. Denman, D. Mackas.)*

Continuous plankton sampling equipment used in these shelf studies and in other situations was improved by adding the capability for counting zooplankton in size classes. This permits a better impression of the make-up of the community. Sampling using ships of opportunity and charters was carried out along a cruise track from Howe Sound to Tahsis

Inlet. This year, for the first time, a rough draft of the data was released within three days of cruise completion, including temperature, conductivity, phytoplankton, chlorophyll, small zooplankton (electronic counter) and solar radiation. The "quick" runs using averaged calibration values suffice for some early warning uses of the data, including, for example, some fisheries management applications. Fully-corrected data were available quite rapidly thereafter.

An attempt to use the same equipment for further work on zooplankton aggregations at salinity fronts was frustrated by dense aggregations of the large planktonic dinoflagellate *Noctiluca*. Experiments with the enclosed ecosystem in cooperation with Ocean Chemistry division involved measuring vertical distribution and timing of grazing. More traditional zooplankton sampling was undertaken in Alice Arm as part of the monitoring study of the Amax mine effluent. *(Contact: D. Mackas.)*

In the laboratory, continuous cultures of phytoplankton were used to study the effect of varying the frequencies of light fluctuations to simulate the vertical movement of the cells in the water column. Development of a microprocessor-controlled turbidostat and a programmable fluctuating light source was initiated in order to maintain the cultures at a constant population density. Oxygen production, cell size and number, chlorophyll content and nutrient concentration will all be monitored to estimate production under near-normal conditions. Results from these experiments will be coupled with theoretical studies of vertical mixing rates in the ocean to develop models for variations in phytoplankton production as a function of their "recent light history" in the upper ocean. These variations in light level experienced by an organism result from changes in ambient light level itself and from changes in the depth of the organisms within the water column that result from turbulent motions. *(Contact: K. Denman.)*

The addition of a photosynthetically-active radiation (PAR) sensor improved the vertical sampling array. Another, interfaced to the data acquisition package, provided ambient values at the sea surface. In combination, these allow measurement of the diffuse attenuation coefficient, which is needed for interpretation of satellite measurements of ocean colour. Two sea-going particle counter-multichannel analysis systems to determine the size spectrum of phytoplankton and zooplankton particles were also developed. Some of the developed equipment was also used by the IOS Ocean Chemistry division and the Pacific Geoscience Centre to measure optical and related physical properties of the water column in relation to sediment loading throughout Kitimat Inlet. *(Contact: S. Hill.)*

Benthos

The IOS benthos program continued to be supported by students and Post Doctoral Fellows. Activities included continuation of studies on reduced oxygen levels in Saanich Inlet and work in Knight Inlet related to high suspended sediment loads. *Pisces IV* performed sixty dives in program support, resulting in 3,000 photographic samples. Professor G. Farrow of the University of Glasgow and Dr. J. Syvitski of the Bedford Institute of Oceanography cooperated in this work. One striking observation involved a forest of gorgonian corals growing on top of the sill at 70 m. Large corals with extended fans that filter particles out of the passing currrent were seen to act as sails and to effectively pluck meter-sized boulders off the sill during peak tidal flows. Other sills were investigated in Jervis Inlet, Howe Sound and Saanich Inlet, adding to the voluminous data on the relationship between currents and animals, and the identity and distribution of the unique, diverse Pacific fauna. This information is being entered into a UNIVAC retrieval system. This work has generated a considerable degree of excitement in North America and Europe, and has been reported in several seminars and conferences. Monitoring of the effects of hurricane Allan on coral reefs in Jamaica, funded by N.S.F., has continued. *(Contact: V. Tunnicliffe.)*

The field sampling sector of a program designed to detect the correlation between the productive and unproductive plankton zones on the shelf, the area suffering at times from reduced oxygen levels, and the fauna of the sea bed underlying these has been completed under contract. Sorting and identifying the catch was started, after which the analysis of results will begin. *(Contact: R.O. Brinkhurst.)*

The oligochaete (sludge worm) toxicity project was successfully completed, linking separate approaches to pollution biology. While some groups of organisms demonstrate different levels of tolerance to specific pollutants in the field, these have not often been used in laboratory tolerance studies. Sludge worms have been used to show how much LC_{50} values of toxicity can be affected by varying simple environmental factors (temperature, pH, salinity), how LC_{50} values relate to survival in nature, and how sublethal responses reveal stresses not seen in normal LC_{50} work. Publications are now in press.

Specimens submitted by pollution biologists, industrial groups and fisheries biologists on a world wide basis have been identified. A theoretical study of evolution in the annelids has been accepted for publication, and several taxonomic reviews have been completed. A guide book to marine oligochaetes is now in press, as is a study of Australian collections. Two students cooperated with these studies, as well as continuing their own work on the *Enchytraeidae* and *Tubificidae*, especially the Pacific coast fauna. Over 7,000 specimens have been examined from British Columbia alone, identifying about 20 new species. Many other new taxa have been described. A third student is completing a study of the squat lobster *(Munida)* by comparing its respiratory physiology with its resistance to oxygen deficits in the field. *(Contact: R.O. Brinkhurst.)*

Ocean Information

The Ocean Information Division supports the management, protection and exploitation of marine resources by gathering and disseminating oceanographic information and data, and by providing a marine environmental review service for the Canadian west coast and western Arctic. The division also provides planning, policy and program analysis, and media relations for the Region.

Arctic and west coast marine data compilation and assessment progress in 1981 exceeded expectations. These activities were sponsored jointly by several government departments and industry and were conducted primarily by consultants under contract. Several reports are scheduled for publication in 1982, following final scientific review, as part of the DFO Fisheries and Aquatic Science Report Series. They include: Physical Oceanographic Data for the S.E. Beaufort Sea, Queen Elizabeth Islands, N.W. Passage, Baffin Bay and the Ellesmere Islands, and Southern B.C. Coastal Waters (Georgia and Juan de Fuca Straits); Chemical Oceanographic Data for the S.E. Beaufort Sea and Environs, and the N.W. Passage; and preliminary stages of Marine Biological Data for Benthos, Plankton, Fish and Whales of the Beaufort Sea.

Several reviews of the suitability of the physical, chemical and biological oceanographic data based for environmental impact assessment and climatology studies proceeded under the supervision of regional scientists. In this regard, an overview of Beaufort Sea industrial development projections, a physical/chemical mass balance comparison of some industrial activities vs. natural variability, and an evaluation of the physical oceanographic factors associated with Beaufort Sea oil spill trajectory modelling were all finalized. In addition, a computerized inventory of Arctic marine environmental assessments and data reports was completed.

The appraisal process also involved participation in the Environmental Assessment and Review Process (EARP). Major contributions were made to committees such as the Regional Ocean Dumping Advisory Committee (RODAC), the Arctic Waters Advisory Committee (AWAC), and the Arctic Offshore Development Committee (ARCOD), in light of the accelerating pace of offshore development in the Beaufort Sea. Joint Administration with Environmental Protection Service (EPS) saw the successful completion of several ocean dumping research projects, a review workshop and a report.

Program analysis and regional planning activities continued to be refined. Considerable effort by IOS senior staff resulted in a well-documented Program Review and Evaluation (PRE) and a five-year Operational Plan for OSS Pacific Region. A considerable number of program analyses and Treasury Board submissions also received regional attention. *(Contact: A.B. Cornford.)*

Ships

Pisces IV being lowered from tender ship.

The IOS Ship Division provided ships, launch, submersible and workshop support during 1981 for Institute, university and other federal agency programs.

CSS *PARIZEAU* (64.3 m overall; 192.9 tonnes)

A/Master: B. Newton *Chief Engineer:* P. Olcen

CSS *Parizeau* was employed for most of the year in support of scientific programs involving the following Institute division: Tides and Currents; Coastal Zone Oceanography; Offshore Oceanography; Ocean Ecology; and Ocean Chemistry. In addition, the *Parizeau* provided support for the geology program of the Department of National Defence. Six weeks of duty as a primary search and rescue (S.A.R.) vessel during the winter herring roe fishery completed the year.

CSS *VECTOR* (39.6 m; 505 tonnes)

Master: K. Sjoholm *A/Chief Engineer:* R. Pearson

CSS *Vector* provided support for the Institute's Coastal Zone Oceanography, Ocean Ecology and Ocean Chemistry divisions. The *Vector* also did sea duty assisting U.B.C.'s Oceanography Department, the Pacific Geoscience Centre and the Environmental Protection Service of the Department of the Environment.

CSS *RICHARDSON* (19.8 m; 78 tonnes)

Master: R. MacKenzie *Chief Engineer:* R. Burrell

CSS *Richardson* spent most of the year in field survey and charting operations for the Hydrographic Division. The Environmental Protection Service was also assisted by the *Richardson* in monitoring studies in Alice Arm. The *Richardson* also spent six weeks as a S.A.R. vessel during the herring roe fishery.

M.V. *PANDORA II*, on charter (58.2 m; 1220 tonnes)

The M.V. *Pandora II* spent most of the year on Canada's east coast, in conjunction with the submersible, *Pisces IV*, assigned to the Bedford Institute of Oceanography.

PISCES IV (6.1 m; 12 tonnes)

Chief Pilot: F. Chambers

The deep-dive submersible *Pisces IV* completed 148 dives in 1981, operating in all three of Canada's oceans. Operations on the east coast, for the Bedford Institute of Oceanography including the Atlantic Geoscience Centre, encompassed work off Sable Island, in the Gulf of St. Lawrence, in the St. Lawrence River, off Newfoundland and Labrador and Baffin Island. Work ranged as far north as Clyde Inlet and as far south as Bermuda as part of a Dalhouse University study.

Barge *PENDER*

The *Pender* acted as mother ship for *Pisces IV* during the first half of the year and later supported the Institute's Hydrographic Division with survey activities in the Okisollo Channel area.

Institute Workshops

The success of the *Hudson 81* Beaufort Sea Survey was in large part due to the work of the depot staff in preparing five Arctic launches. In addition, depot staff completely refitted the launches *Revisor*, *Sprite*, *Sparrow*, *Dove* and *Dellquay* and provided overhaul and maintenance support to *Vector*, *Richardson* and *Parizeau*.

Deck Machinery

Deck Machinery supplied equipment and serviced over 40 major items of support gear for various scientific cruises. Service was also provided during CSS *Hudson's* visit in May and June. Maintenance of support gear to service ships for the Institute, Ministry of Transport, Department of National Defence and various contractors is ongoing.

Management Services

Management Services encompasses the central support services of the Institute — financial and material management, administration, purchasing and library services.

The Marine Technology Centre, built by the British Columbia Development Corporation under federal-provincial auspices, on land adjacent to IOS, was completed and officially opened in June of 1981. Private companies engaged primarily in marine research, development and marketing now fully occupy the centre.

In order to cut energy costs, four solar heating systems were installed for the supply of domestic hot water. This resulted in reduced consumption of oil and electricity. In order to assess the possibility of further energy savings, a contract was let to examine the various mechanical and electrical systems in the Institute.

Twice weekly public tours of he Institute, conducted by the Canadian Corps of Commissionaires, attracted 1,977 visitors during 1981.

The response to the library's new computer-based catalogue has been favourable. A series of refinements were made this year, making the system more adaptable to user requirements. Interest in the system has been expressed by other libraries, including the Maritime Museum of Monaco. The number of library users has increased dramatically as a result of the Marine Technology Centre coming on-line.

DEPARTMENT OF THE ENVIRONMENT

Atmospheric Environment Service

The main scientific activity during 1981 involved continuation of the analysis and interpretation of the Storm Transfer and Response Experiment (STREX) data set. This experiment was a major air-sea interaction study of storms over the northeast Pacific Ocean. A detailed intercomparison of wind tracking capabilities of the ship-borne radar and the NAVAID system has shown that in most cases there was a very good agreement. Most of the bad NAVAID wind values could be removed by simple vertical smoothing. Generally, the average difference between the two systems was less than 8% of the measured wind. A report is almost complete.

An important characteristic of storms is their associated warm and cold fronts. Along these frontal surfaces abrupt changes in meteorological parameters occur, usually accompanied by the most intense weather. The frontal system of November 17, 1980 (briefly described in the 1980 annual report) has been the subject of further study. A comparison of the frontal structure as it passed over CCGS *Vancouver*, and over NOAA's *Oceanographer*, four degrees longitude further east, has shown that the basic structure remained the same but with some important changes in detail. The temperature difference across the cold front became smaller but the moisture content in the warm sector was enhanced. Particularly noticeable was the increasing temperature and decreasing moisture in the region between 500 and 800 mb behind the cold front. This is associated with descending air behind the cold front and low-level divergence.

The second major program entailed collection and chemical study of precipitation in oceanic and coastal regions. Observations at coastal locations in B.C. suggest that the acidity of the rain was slightly more than has been traditionally assumed for unpolluted areas. In order to investigate this more fully an observational program to collect precipitation samples from IOS ships and snow samples at Mount Washington on Vancouver Island was started. The precipitation samples are being analysed for major ion constitutents and total acidity at the Inland Waters laboratory in North Vancouver. As yet the results are not numerous enough to draw any conclusions but it is certainly evident that events of high acidity precipitation do occur both along the coast and out over the northeast Pacific Ocean. The origin of the sulphates and nitrates in the samples is not yet clear but is likely a combination of natural marine aerosols and the background air pollution levels that are now worldwide. Over the ocean in particular the measured acidity of open ocean samples is particularly enhanced by the relatively low occurrence of precipitation.

A third area of activity has been in studies of turbulence and mixing in the earth's boundary layer. Results on the spectral shape and empirical constants for the spectrum of microscale temperature fluctuations were found to be in general agreement with previous findings. However, the enhancement of the spectrum at scales where the molecular effects dominate were not observed. It is not yet clear why this is observed in some results and not in others.

The effects of larger-scale atmospheric turbulence were studied in cooperation with a summer student. A model for the development of the mixed layer and its effect on pollution diffusion was applied to a single tall-stack source of pollution. Significant changes in the ratio of dry deposition of pollutant to what is retained for later precipitating out, were caused by varying the mixed layer depth throughout the course of a day. *(Contact: G.A. McBean.)*

Canadian Wildlife Service

The Canadian Wildlife Service (CWS) is responsible under the Migratory Birds Convention Act for the preservation of migratory birds. Migratory birds among others include birds at sea, birds along marine shores and those in marine breeding colonies. In order to assist preservation of marine birds, CWS studies their numbers and seasonal distribution at sea, their food habits and their feeding, and their staging and nesting habitats. Seasonal observations on the birds' food habits and feeding, staging and nesting habitat may show "why" the birds are there Data on the '"where, when and why" of marine bird populations aid in delineating marine bird concentrations and vulnerable marine bird habitat.

In conjunction with other colleagues, work has continued on the assembly of an atlas detailing the distribution and density of marine birds along Canada's west coast. Chevron Canada Ltd. has been assisting with the preparation of the atlas to make it available for he environmental hearings relating to B.C. offshore development activity.

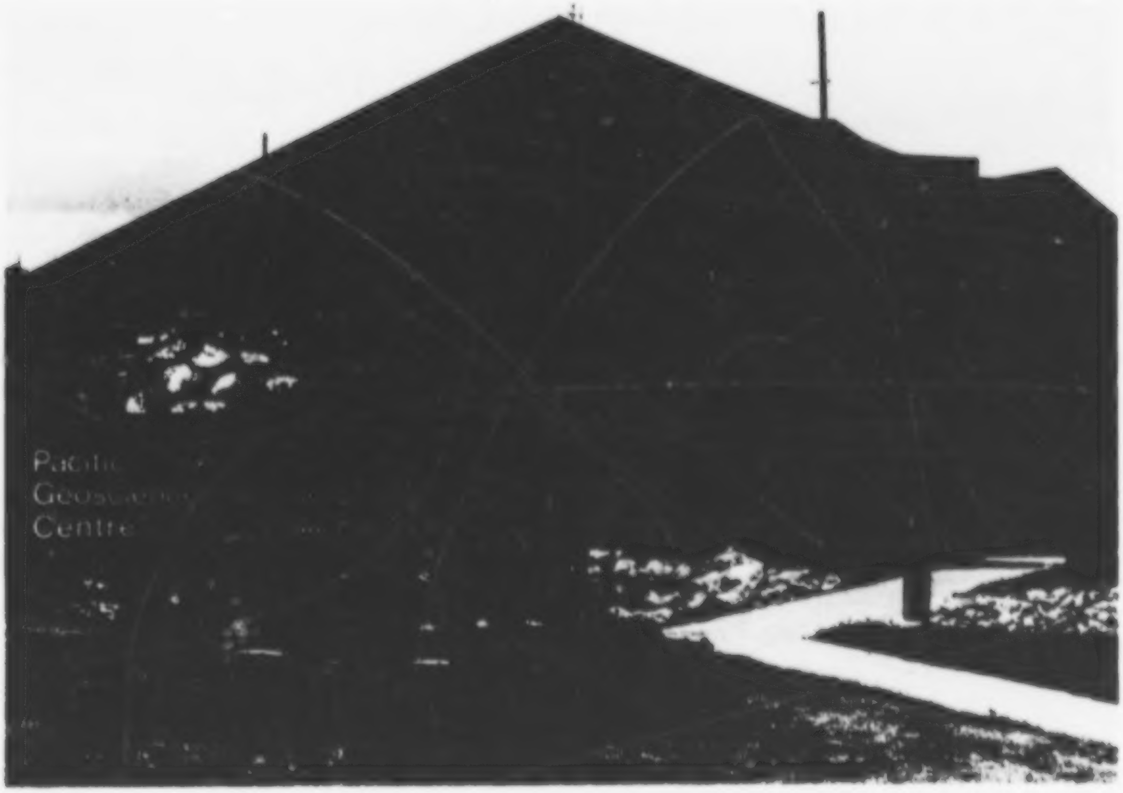
Cooperative cruises for next summer are planned by CWS, the Pacific Biological Station (DFO) and IOS to study the distribution and density of marine birds in relation to their foods and physical oceanographic parameters in the Queen Charlotte Sound and Hecate Strait. Possible future offshore drilling may afffect both the birds and their prey.

Studies on the feeding ecology of marine birds and the effects of mine tailings on coastal marine life were undertaken and will also be continued on Canada's west coast in 1982.

One investigation of the effects of the El Salvador copper mine in Chile on marine intertidal life and marine birds initiated in the autumn of 1981 as part of CWS/Latin American program will be continued in the spring of 1982. *(Contact: K. Vermeer.)*

DEPARTMENT OF ENERGY, MINES AND RESOURCES

PACIFIC GEOSCIENCE CENTRE



Pacific Geoscience Centre at IOS.

Earth Physics Branch and Geological Survey of Canada

Chief Scientist's Foreword

The purpose of the earth science program is to provide geological and geophysical information on the evolution, structure and dynamic processes of the solid earth and the hazards associated with natural and induced geological processes, with special reference to the western Canada land mass and offshore regions.

The projects described on the following pages have provided data for a number of aspects of these broad objectives. In particular, marine programs have provided data for the development and extension of ideas about contemporary and past plate motions along the western continental margin. These studies, coupled with expansions of the seismological network, levelling, and geodynamic surveys, are continually improving understanding of earthquake mechanisms, frequency and risk. Systematic marine surveys in cooperation with the Hydrographic Service are also playing a vital part in providing a data base for the evolution and understanding of the mineral resources that may occur in Canada's western offshore areas.

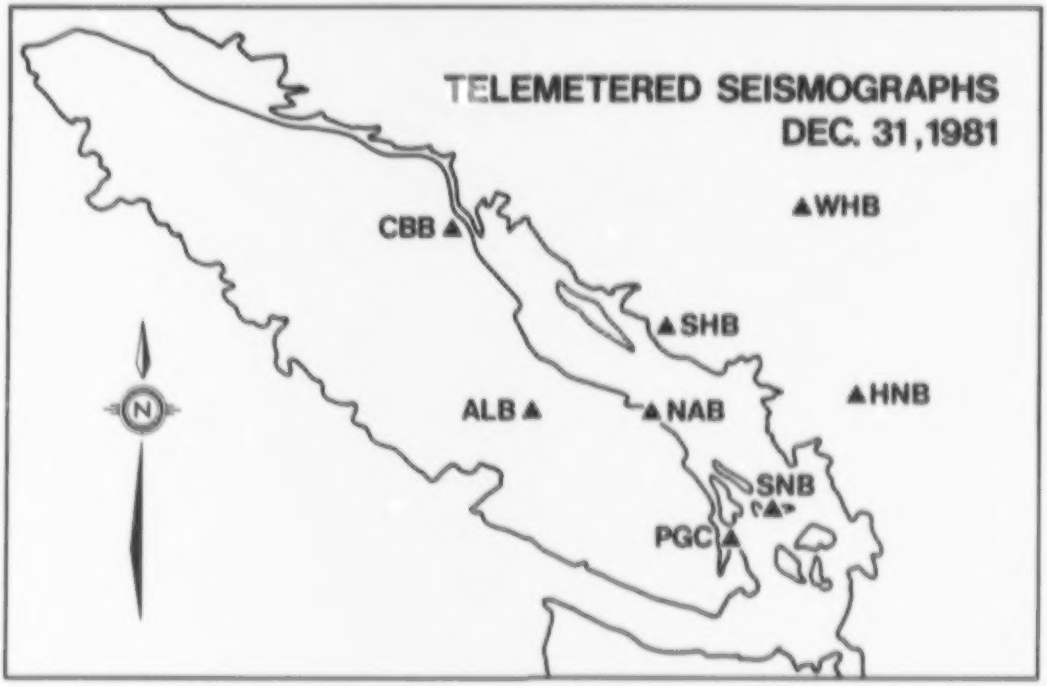
Geological studies have been directed towards an understanding of the history of the rock formations along the margin and of the deposition, composition and stability of sediments on the continental shelf and in coastal inlets. These studies provide input both into resource evaluation and into assessments of the environmental impact of the wide range of construction and development projects occurring along the coast and of offshore petroleum exploration.

Inland, geothermal studies continued to explore and delineate alternative energy sources and to provide important scientific information about deep crustal structure. Gravity surveys in the Rocky Mountains continued as part of the long-term regional coverage of the northern Cordillera, now the principal remaining gap in the National Gravity Data set.

During the year, a number of new staff joined the Pacific Geoscience Centre (PGC) and there was one important retirement. The Chief Scientist, Dr. W.G. Milne retired after 35 years of government service and 30 years on the west coast. Dr. Milne was transferred to Victoria to operate the seismological observatory soon after the 1946 Vancouver Island earthquake. He presided over a number of organisational changes and expansions culminating with the Victoria Geophysical Observatory and the Marine Geology Section of the Geological Survey being combined into the Pacific Geoscience Centre in 1978. The scientific success of PGC owed much to his quiet but strong supportive style of management and he will not be easily replaced.

Seismological Service

The Seismological Service provides earth scientists, civil engineers, resource development industries and the public with basic earthquake data, and with research information concerning natural and induced earthquakes, ground motion, seismic risk, earth structure, and nuclear explosions. This is accomplished through a network of seismological stations, including standard and regional stations, two telemetered arrays, strong motion accelerographs, and special installations.



The West Coast Telemetered Network (WCTN) for earthquake monitoring currently comprises 8 seismic stations whose signals are transmitted to a central computer at PGC. Automatic monitoring of these signals permits virtually on-line location of seismic events in southwest British Columbia.

Seismic Networks

The Western Canada Telemetered Network (WCTN), established in order to provide centralized, on-line monitoring of seismicity in southwestern B.C., was expanded in 1981 through the installation of a radio link at Saturna Island which permitted the addition of stations at Sechelt and Campbell River. A telephone-linked station was also added at Whistler, B.C. which will permit seismic monitoring of any future volcanic activity in British Columbia's Garibaldi volcanic belt. Six stations were being recorded at PGC at the end of the year. Preparatory site work was also completed for an additional six stations. The network located almost 200 small earthquakes in the Vancouver Island - Strait of Georgia region in 1981. *(Contact: D.H. Weichert, M. Bone, A. Whitford.)*

The strong motion seismograph network in western Canada, which consists of instruments designed to operate and record ground acceleration only when very strong (½% of normal gravity or larger) earth motion occurs, remained at 36 accelerographs, although some site changes were made. During 1981, 61 auxiliary strong motion instruments called seismoscopes were decommissioned. *(Contact: D.H. Weichert, H. Bennetts.)*

In 1981, the responsibility for locating and cataloguing earthquakes in western Canada was transferred from the Earth Physics Branch in Ottawa to the Pacific Geoscience Centre. Over 700 earthquakes were located in western Canada in 1981. *(Contact: R. Horner.)*

Special Earthquake Studies

In separate cooperative projects with Dome Petroleum Ltd. and B.C. Hydro and Power Authority, seismograph stations were set up to monitor earthquake activity for local seismic risk estimates in the Beaufort Sea region and in northern British Columbia. The seismograph records are sent to PGC for analysis. Beaufort Sea seismicity was also studied by deploying ocean bottom seismographs in a cooperative project with the Atlantic Geoscience Centre and Dome Petroleum Ltd. *(Contact: D.H. Weichert, G.C. Rogers.)*

A two-month field project was carried out in the Frank Slide area in southwestern Alberta where residents had felt minor tremors. Some microearthquakes were observed in the region but none that could be associated with the slide itself. *(Contact: D.H. Weichert.)*

The earthquakes occurring within the subducted oceanic Juan de Fuca plate beneath southwestern British Columbia have been studied and a source-mechanism hypothesis based on volume and density changes resulting from phase changes has been developed. *(Contact: G.C. Rogers.)*

A study was completed relating the earthquake occurrence rate to relative plate motion rates along Canada's western margin. In most regions there is good agreement between the two, but the convergent margin of southwestern B.C. and Washington appears to require considerable aseismic motion. *(Contact: R.D. Hyndman, D.H. Weichert.)*

A study of the earthquake rate in British Columbia's recent volcanic zones showed a slightly higher rate of small earthquakes there than in the surrounding regions. However, no earthquakes could be associated with any particular volcano. *(Contact: G.C. Rogers.)*

Seismic Risk Estimation

PGC continued to produce site specific risk estimates for many engineering projects in western Canada. New techniques for risk calculation were investigated and considerable progress was made towards the generation of the base maps that will form the basis of a new national seismic zoning map for Canada. *(Contact: D.H. Weichert.)*

Earth Structure by Seismic Methods

One of the most important techniques for determining the deep structures and properties of the earth is the study of waves propagated by explosions or earthquakes. The principles and many of the techniques are similar to those applied by the petroleum industry to the study of sedimentary basins and their structure. The work includes a wide range of theoretical and field investigations including deep crustal and shallow sedimentary programs. The deep crustal programs are directed mainly toward defining the structure in the principal earthquake generating zones along the continental margin.

Theoretical Studies

The theory of resonant scattering for fluid-filled inclusions has been applied to seismological configurations. It has also been extended and applied to wavefield inversions for refraction and reflection interpretation of crustal structure. Previously developed techniques for the inversion and modelling of seismic refraction data have ben applied to the data from a major seismic experiment, VISP-80, across the margin of southwest British Columbia. Analyses have also been carried out on data from California and from Antartica.

Further studies have been conducted on the techniques of wavefield transformation and wavefield continuation. *(Contact: G.A. McMechan.)*

Field Studies

The structure and subsidence history of the Queen Charlotte Basin has been studied using data from seismic profiles, Shell Canada Resources Ltd. well data, and data obtained in cooperation with the University of B.C. in recent seismic refraction studies using a large airgun (32 litres) and sonobuoys. The basin has been modelled in terms of flexure of the continental lithosphere generated by underthrusting along the margin and the formation of a rift in Queen Charlotte Sound. *(Contact: C.J. Yorath, R.D. Hyndman.)*

The analysis of the structure of the Winona Basin off northern Vancouver Island has been continued by applying the theory for sedimentary anisotropy to seismic refraction and reflection data. *(Contact: E.E. Davis.)*

Deep Sea Drilling Project

A leg (78B) of the Deep Sea Drilling Project (DSDP) re-occupied a deep crustal hole on the mid-Atlantic ridge for a wide range of downhole geophysical measurements. They included: a complete suite of commercial well logs, downhole temperature, downhole magnetometer, televiewer, water chemistry, and a packer permeability experiment. There was also the emplacement of a downhole seismometer for use in an oblique seismic experiment in conjunction with ocean bottom seismographs. The results have provided considerable new information on the deep strucuture, physical properties and state of the oceanic crust. *(Contact: R.D. Hyndman.)*

Geothermal Studies

The earth's temperature influences both rock properties and geological processes. Thermal data, particularly surface heat flux, are among the most important indicators of deep tectonic processes and the structure of the earth's crust. Most active tectonic processes that result in mountain building, earthquakes and volcanism originate from thermal energy. In addition, the earth has considerable economic potential as a heat source for geothermal energy.

Measured thermal parameters include surface heat flux (the result of vertical temperature gradient multiplied by the thermal conductivity of the rocks), and heat production from natural radioactive decay in crustal rocks (for example, thorium and potassium). Studies cover a wide range of geological and geophysical interests — from heat flow, heat production and thermal processes in the deep sea floor, to the discovery and development of geothermal energy resources in western Canada.

Land Studies

There is a continuing program to determine the regional geothermal heat flow pattern from borehole measurements in the Canadian Cordillera. These data can be used in the interpretation of regional tectonics and structure, and in the delineation of hot areas with potential for geothermal energy development. In south central British Columbia, several deep boreholes have been drilled in and near Tertiary sedimentary basins that may be hot water sources for economical space heating. A profile of shallow (100 m) geothermal heat flow boreholes have also been drilled across south central B.C. as part of a general regional evaluation. Studies are continuing in the Garibaldi Volcanic Belt where at Meager Mt., B.C. Hydro and Power Authority has recently drilled potential steam production wells. *(Contact: T. Lewis.)*

Marine Studies

A series of repeat marine-probe heat-flow measurements has been carried out up the length of Jervis Inlet to investigate further the previously observed increase of heat flow as the Garibaldi Volcanic Belt is approached. The large increase in heat flux by a factor of two is observed to take place near the head of the inlet over a distance of 20 km. *(Contact: T. Lewis.)*

Marine heat flow data from the deep water Winona sedimentary basin off northern Vancouver Island have been analyzed, and, along with other geophysical data, indicate the youth of the sediments and underlying oceanic crust. The estimated high temperatures in the sediments also help explain the unusual seismic velocities observed. *(Contact: E.E. Davis.)*

A suite of new heat flow measurements across the Queen Charlotte fault zone substantiates a model of ocean floor underthrusting beneath the Queen Charlotte Islands. Additional measurements were also made in Queen Charlotte Sound to evaluate a proposed rift or extension origin for this area. *(Contact: R.D. Hyndman.)*

The heat flow in Hecate Strait and Queen Charlotte Sound has been estimated using older data from wells of Shell Canada Resources Ltd. These results and paleoheat flow from vitranite reflectance data have been employed to constrain thermal models for the area and estimate probable petroleum maturation. *(Contact: R.D. Hyndman, C.J. Yorath.)*

Deep (10 m) piston corer-outrigger sensor heat flow measurements over Mesozoic sea floor in the northwestern Atlantic were carried out to confirm the results of the previous year's multiple penetration instrument (3 m) survey. The heat flow is found to be constant from 110 to 150 Ma and higher than that predicted by lithospheric plate or boundary layer cooling. *(Contact: E.E. Davis.)*

Repeat temperature measurements in Deep Sea Drilling Project Leg 78B have resulted in an interpretation in terms of downward seawater flow into permeable crustal horizons. Downhole temperatures into old Atlantic sea floor (DSDP site 534) have shown agreement with nearby marine probe measurements. A review of all recent DSDP heat flow measurements has also been undertaken. *(Contact: R.D. Hyndman, E.E. Davis.)*

Gravity

The principal task of the Gravity and Geodynamics Division is to establish the shape of the geoid in Canada to the highest standards and to determine the value of gravity on a regional basis over the Canadian landmass and offshore areas. The geoid is the reference surface for all surveying and mapping. The regional gravity data provide information for both the determination of crustal structure and the evaluation of resources and are critical to the operation of inertial navigation systems used by defence agencies for submarines and missiles.

Seaborne operations in 1981 aboard CSS *Parizeau* covered an area of 87,000 km^2 on a systematic 10 km line spacing out to the 200 mile limit west of the Queen Charlotte Islands. Two La Coste and Romberg dynamic gravimeters were operated simultaneously: SL1, the "linear" prototype meter tested in 1980 and a three-axis "beam" meter, S41. Comparison of the two systems again showed that the linear meter performed with greater accuracy. In particular, because of the reduction of cross-coupling due to ship movement, it was much more tolerant of rough water.

The 1981 survey will be integrated with the continuing series of regional offshore surveys for publication in 1982. A suite of extended single tracks cutting across the offshore region was successfully used to provide the basis for a mutual adjustment and calibration of these surveys into one coherent data set comprising all west coast marine gravity data.

Land regional gravity surveys by helicopter were continued under contract in the Jasper-Edson area of Alberta and British Columbia by Terra Surveys Ltd. As in previous years, a combination of existing monumentation and inertial navigation was used to provide the required ±50 m horizontal and ±3 m vertical control. Three hundred new stations were observed including one on the summit of Mt. Robson at 3950 m. *(Contact: R.P. Riddihough, D. Seemann.)*

Geodynamics

In the active tectonic region of Canada's west coast, the major subject of study for geodynamics is the effects of contemporary crustal deformation. A principal objective of such studies is to establish realistic dynamic models of crustal plate interactions and their accompanying earthquakes in this region. Efforts to measure crustal strain using precise gravimetry continue on central Vancouver Island in the region of the 1946 earthquake. Semi-annual gravity surveys since 1977 continue to show regional gravity field changes of the order of 3 to 5 μGal/a (1 μGal = 10 nm/s^2). Although a tectonic origin cannot be ruled out, it is thought that secular variations in local hydrology may be the principal cause of these gravity variations.

The measurement of small changes in elevation over periods of a few years is extremely difficult especially in regions with limited road access. Using very sensitive gravimeters transported by helicopters or float-aircraft, vertical strain measurements can be carried out over long distances in the rugged terrain of Canada's west coast.

In an attempt to measure differential vertical strain over longer ($\sim$100 km) baselines, a precise gravity profile was established between the Tofino and Pt. Atkinson tide gauges using float-aircraft for instrument transport. This innovative survey method proved extremely successful. Relative gravity values were established to a precision of 2 μGal which should allow resolution of future elevation changes of the order of 1 or 2 cm.

Work preliminary to the measurement of horizontal crustal strain was also initiated. For the eventual precise measurement of baselines of up to thousands of kilometres using VLBI (very long baseline interferometry), the site of the Dominion Radio Astrophysical Observatory at Penticton was investigated for possible use in conjunction with NASA's ARIES program. On a more local scale, the sites of a 1947 horizontal triangulation network in the Gold River area were recovered for future trilateration measurements. It is hoped that the precise measurement of baselines up to 40 km in length with laser-ranging instrumentation will allow future strain estimates of the order of 1 part in 10^7. *(Contact: H. Dragert.)*

Geomagnetism

The Geomagnetic Field

The earth's geomagnetic field varies both spatially and temporally. This inherent variability of the geomagnetic field is well known and is exploited in a variety of ways. To be utilized for navigation, the magnetic field and its gradual change with time must be determined as a function of latitude and longitude. Changes in the magnetic properties of rocks also lead to spatial variations in the magnetic field which become characteristic signatures of structure, composition, and the thermal history of crustal rocks. Short-period temporal changes in the magnetic field must be monitored in order to resolve subtle spatial field variations as encountered in exploration geophysics.

In Canada, the geomagnetic field is monitored continuously at 13 primary observatory sites and discontinuously at about 140 secondary sites. As part of this Canadian Geomagnetic Network, the Pacific Geoscience Centre operates the Victoria Geomagnetic Observatory (VGO) on property near the Dominion Astrophysical Observatory. In the fall of 1981, a third generation Automatic Magnetic Observatory System (AMOS) was installed here. This system, which uses both fluxgate and proton precession magnetometers, now features self-diagnostic testing, variable sampling rates, and remote data retrieval via a telephone modem to a central repository in Ottawa.

The Pacific Geoscience Centre also collects magnetic field observations at the 15 repeat stations in British Columbia. These measurements, repeated 2 - 3 times every 5 years, provide the secular variation data that supplement the primary network. These data are used in updating maps of the geomagnetic field components for the Canadian land mass every 5 years. During the summer of 1981, measurements were obtained at 3 of these sites.

Geomagnetic Variations

Temporal variations in the earth's magnetic field provide a source of electromagnetic energy with which to probe the earth's electrical conductivity structure. Zones of high conductivity, if related to high temperatures and partial melting, can be used to define areas of geothermal interest. Geomagnetic depth-sounding can also determine the thickness of the cold lithospheric plate riding over the asthenosphere, an important parameter in understanding the active tectonic regions dominant on the west coast.

Confirmation that the cold Juan de Fuca lithospheric plate does indeed dip beneath the continental mass under Vancouver Island has been derived from an analysis of the geomagnetic data obtained in a 1980 experiment. Experimental results also imply that the thickness of the Juan de Fuca plate increases with its age, substantiating previous studies.

Ocean bottom magnetometers (OBM) have proved to be excellent sensors for measuring the magnetic signatures of mass water transport, such as those attributed to the lunar semi-diurnal tides. Good recordings of deep water tides have been obtained at the two sea floor sites: the base of the continental slope (2200 m water depth) and 80 km further west on the abyssal plain (2700 m water depth). Shorter period fluctuations (less than 1 hour) associated with oscillatory current flows have also been measured for the first time in deep waters. Preliminary research suggests that an oceanographic edge wave along the continental slope may be responsible for these shorter period magnetic signals.

The Pacific Geoscience Centre is also developing a unique geophysical instrument to determine the distribution of electric conductivity in the first few tens of kilometers beneath the seafloor. Usually OBMs measure the earth's natural magnetic field variations; alternatively, an artificial source of electromagnetic energy can be generated by placing a vertical wire from the sea surface into the sea bottom and pumping electric current through the cable. The resulting magnetic field is measured by OBM sensors on the seafloor. From these observations a knowledge of the conductivity of the sediments and the crust beneath the ocean can be deduced. The theory has been worked out and a test of the procedure was done in November 1981, in the Strait of Georgia. The precise positioning required to maintain an exact, known geometry between the source cable and the OBMs was successfully achieved.

In order to determine the conductivity structure beneath Vancouver Island more precisely, many samples of variations in the electromagnetic field components are required over a number of sites. Consequently, in 1981, two sites were selected in central Vancouver Island and measurements of the electromagnetic field were obtained. Repeated observations at these sites will be done in the future in order to monitor possible temporal changes in crustal conductivity structure.
(Contact: L. Law, J. DeLaurier, D. Auld.)

Paleomagnetism

The paleomagnetism of rocks records the variations in directions of the geomagnetic field in the geological past. The intensity of the ancient field is also recorded but is much more obscure and difficult to observe and can only be obtained in very favourable circumstances. The principal application of paleomagnetism is in tectonics — the study of the motion of continents, the opening and closing of oceans and the origin of mountain belts -- but it is also used widely in many problems of stratigraphic correlation, the origins and thermal history of rocks, and in the source and origin of magnetic anomalies.

The paleomagnetic laboratory currently being installed at PGC includes two microprocessor controlled spinner magnetometers used to measure the remanent magnetic fields in rock samples. The raw data are communicated directly to the mainframe computer for analysis.

A new paleomagnetic laboratory is currently being installed at PGC. Work will be related mainly to studies of the tectonics of the Cordillera and the western Arctic and to magnetostratigraphic studies. During the last decade, geological and geophysical studies have shown that the Cordillera comprises a number of distinct crustal blocks. Vancouver Island is one such block. Paleomagnetic work has shown that these blocks have been transported from the south by distances over 1000 km, much of central British Columbia once being in the latitude of California. Vancouver Island could have moved northward by over 5000 km relative to North America and may even have originated on the other side of the Pacific Ocean. The western Cordillera, therefore, appears to be a collage of small crustal fragments that originated elsewhere, were carried over large distances, and finally glued to North America. This discovery has led to a profound revision of our ideas about the origin of this and other mountain belts. *(Contact: E. Irving.)*

Geological - Geophysical Studies

Systematic magnetic, gravity and bathymetric surveys are being conducted over the Canadian Economic Zone to help assess the economic potential of the region and its tectonic framework. The 1981 Resource Mapping Program survey was conducted between 180 and 360 km west of the Queen Charlotte Islands (approx. 50°N to 54°N). Continuous magnetic, gravity and bathymetric data were collected in 7700 km of survey and tie lines in this previously unsurveyed area of the northeast Pacific. The new magnetic data exhibit an extremely regular sequence of north-northwest trending oceanic anomalies with little evidence of offsets or transformations and a half-spreading rate of approximately 3.0 cm/year. The most striking bathymetric features were two submarine channels striking subparallel to the magnetic anomalies. *(Contact: R. Currie.)*

Geological studies on the Queen Charlotte Islands and concurrent geophysical programs in Hecate Strait and Queen Charlotte Sound have led to new interpretations of the tectonic history and petroleum potential of Queen Charlotte Basin. The recognition of the origin and timing of collision of exotic crustal fragments and the rift origin of Queen Charlotte Sound has permitted new geophysical modelling of the dynamics and thermal history of the basin. Two possible sources of hydrocarbons are indicated. The first is related to the possible occurrence of petroliferous Upper Triassic and Jurassic rocks beneath southern Hecate Strait similar to those observed on the Queen Charlotte Islands. Rifting in Queen Charlotte Sound possibly has allowed these older hydrocarbons to migrate upward along faults to become trapped within the Tertiary sediments. The second source for hydrocarbons lies within the Teritiary sediments themselves. The subsidence and thermal history of the basin suggest that sufficient metamorphism of organic matter would have occurred. If petroleum source rocks are eventually found, favourable reservoir rocks within the basin may contain liquid hydrocarbons of Tertiary age. *(Contact: C.J. Yorath.)*

Paleontology

Activities in Paleontology at the Pacific Geoscience Centre are focused on micropaleontological biostratigraphy of Mesozoic and Cenozoic rocks of the complex Pacific margin of Canada. Work is continuing in studies of Tertiary biostratigraphy both on land and offshore with emphasis on depositional environments and planktonic foraminifers. Ultimately, this study should assist in understanding the tectonic evolution of the west coast and its potential for oil and gas exploration. In connection with the latter, a very successful two-day symposium was held at PGC in February. This meeting was designed to familiarize the oil industry with the tectonics, sedimentary history and possible hydrocarbon occurrences in the offshore areas of British Columbia.

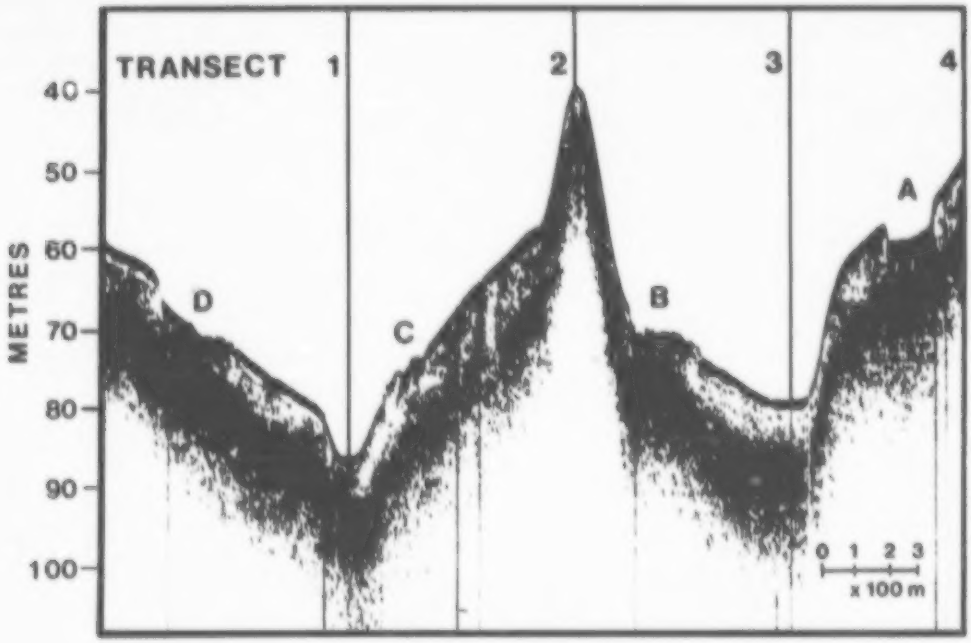
The geology and biostratigraphy of the Jurassic rocks of the Queen Charlotte Islands are currently under intensive study. This work includes microfaunas (Cameron, PGC) and ammonoid faunas (H.W. Tipper, GSC, Vancouver and H. Frebold, GSC, Ottawa).

A Master's thesis supervised by B. Cameron was completed by M.L. Malott in 1981 at U.B.C. It dealt with the distribution of Holocene foraminifers from deep sea cores off the Pacific margin. Malott and Cameron are continuing studies on foraminiferal and ostracod distributions in Quaternary sediments of the west coast. *(Contact: B. Cameron.)*

Sedimentology

Estuarine and Marine Delta Sedimentation

Demand has continued for geological data from the Fraser Delta which can contribute to the formulation of environmental/engineering guidelines. This past year, attention has been focused on assessments of



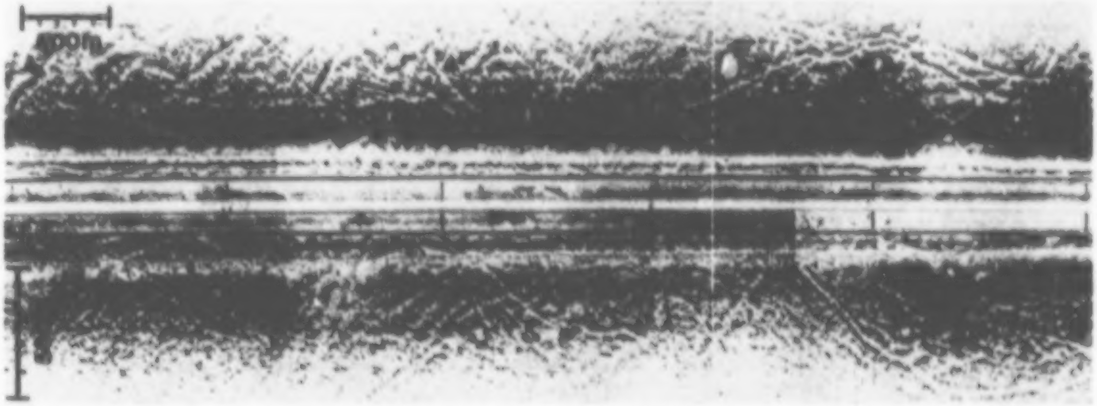
Bathymetric profiles of the head of the Fraser River Delta Slope off the Iona Island Sewage Treatment Plant outfall channel. The record depicts successive transects across the same corridor and suggests the presence of a slump generated trench and associated downslope deposits: A. trench. B. slump deposit. C. slump deposit. D. intermediate trench/slump deposit morphology.

the stability of the Fraser Delta slope. The research has included analyses of sedimentologic, geotechnical, morphologic and bathymetric data and has been performed in conjunction with the Soil Dynamics Group in the Department of Civil Engineering at the University of British Columbia. *(Contact: J.L. Luternauer.)*

Continental Shelf Sedimentation

A study of the late Quaternary morphology/sedimentation in Queen Charlotte Sound, completed in 1981, established that much of the shelf reflects the widespread effects of Pleistocene glaciation; both broad glacier scoured troughs containing ice-contact deposits and well-defined iceberg furrows are still apparent. The oceanographic climate which prevailed when sea level was lower probably determined the depth of the present shelf break and contributed to the concentration of heavy minerals on banks and to the formation of canyons which crease bank margins. The little terrigenous material that has been supplied to the shelf during the Holocene is accumulating near the mainland coast. Elsewhere on the shelf the principal post-glacial deposits are forminiferal and mulluscan skeletal detritus which can be dominant components of bank sediments. *(Contact: J.L. Luternauer.)*

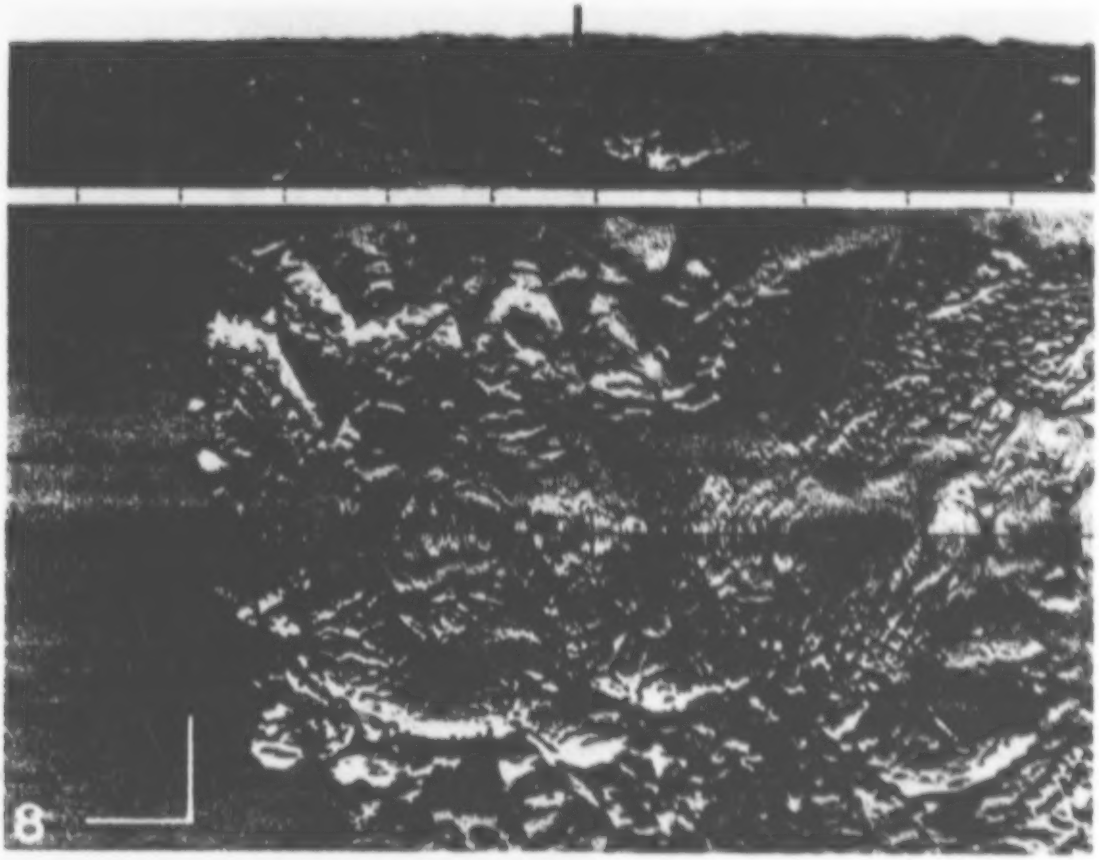
A joint cruise with scientists from Western Washington University was undertaken to southern Hecate Strait to study the morphology and sediments on a broad bank approximately 2500 km^2 in area. Traditional geological opinion has held that shallow marine carbonate sedimentation is essentially confined to tropical and subtropical latitudes. There is growing evidence that under appropriate conditions, carbonate-rich sediments can develop on continental shelves at any latitude. This investigation was carried out to learn more about such high-latitude biogenic and mixed biogenic-terrigenous sediments. Much of the bank is covered by a veneer of coarse sands and gravels, in places composed entirely of shells and shell fragments. Across this gravel and shell pavement in the interior of the bank are frequent narrow, long "ribbons" of sand formed into oscillation ripples and mega-ripples up to 2 m high. The edges of the bank, where fine sands dominate, are characterized by asymmetrical current ripples up to 4 m high with wavelengths of 10 m or more. *(Contact: B. Bornhold.)*



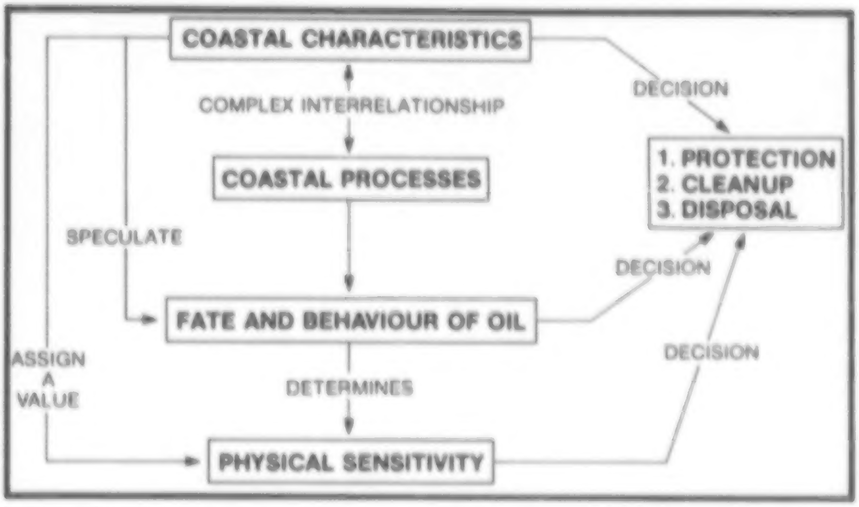
Side-scan sonogram of criss-crossing iceberg furrows at a depth of about 170 m on the inner shelf of northern Queen Charlotte Sound.

Fjord Sedimentation

Through a recently established program for joint research between the United States Geological Survey and the Geological Survey of Canada (GSC), a cooperative project was undertaken in Kitimat Arm, Dean Channel and Howe Sound involving scientists from the Coastal Studies Institute of Louisiana State University and Texas A&M University. The aim of the study was to investigate the morphological and geotechnical aspects of large submarine slides on or near fjord deltas. These slides have, in the past, caused considerable damage to shoreline structures and continue to pose a geologic hazard to coastal development. The well-documented slope failure of April 1975, in Kitimat Arm was extensively surveyed using a digital side scan sonar seabed mapping system, a 3.5 kHz sub-bottom profiler, seabed photography and piston and gravity corers. The disturbed sediments from the slide extend more than 4 km down the centre of the inlet, having a volume of approximately $60 \times 10^6 m^3$, and in places are up to 25 m thick. *(Contact: B. Bornhold.)*



Side-scan sonography across the toe of a submarine landslide in Kitimat Arm, B.C., showing contorted marine muds on the right against undisturbed basin sediments on the left. Scale bar is 25 m.



Schematic diagram illustrating the rationale for using coastal geology in oil spill contingency planning. Coastal characteristics as defined by geomorphology and sedimentology must be used to infer active processes which ultimately determine the fate and behaviour of oil. This expected dynamic behaviour of the oil spill along with the physical sensitivity of the coastline provide the basis for decision making.

Coastal Studies

Coastal sedimentology and geomorphology are studied to (i) provide a data base for port location, industrial development, and shoreline management and recreation, (ii) develop oil spill contingency plans including an assessment of the fate and behaviour of oil in the coastal zone and cleanup techniques and, (iii) elucidate the geological evolution of British Columbia's coastline.

To achieve these aims, six locations throughout the Strait of Juan de Fuca, the Gulf Islands and the Strait of Georgia were chosen, each location containing a variety of environments representative of the coast. About 500 sediment samples were collected for sediment textural analysis which, when complete, will provide not only a description of each of the facies encountered in the beach and nearshore zones, but also the basis for understanding the sedimentary dynamics of the coastline. In addition to sampling, beaches and nearshore environments at each location were surveyed, the latter with both an echo sounder and sub-bottom profiler. A SCUBA program enabled first-hand observation of the submarine environments.

These surveys were used to develop a process-response model to describe the evolution of the beach nearshore system within the Strait of Georgia. The nearshore profile develops a characteristic shelf form. The width of the shelf and depth of water at the shelf break increase with exposure to wave energy. Statistical relationships between the wave climate, shelf morphology, and sediment distribution provide a model of the shelf as an equilibrium size-graded form, similar to prograding shelves on the continental margins. *(Contact: P. McLaren.)*

APPENDIX I

CONTRACTS AWARDED 1981/82

Study of Benthic Community Structure and Dynamics on the Southwestern Continental Shelf of Vancouver Island	Dobrocky Seatech Ltd., Sidney, B.C.	$420,000
Preparation of Oceanographic Data and Scientific Diagrams Using Data from Charts, Tables and Records	C. Wallace, Sidney, B.C.	8,044
Numerical Modelling Studies of the Estuarine Circulation in the Strait of Georgia System — Phase III	University of British Columbia, Vancouver, B.C. (Dr. R.W. Burling)	19,000
Development of Techniques for Analysis of Langrangian Oceanographic Data from Drifting Buoys	J. Papadakis, Victoria, B.C.	33,350
Oceanographic Observations Aboard C.C.G.S. QUADRA Cruise No. 81-004	H. Ashton, Nanaimo, B.C.	6,379
Finite Element Analysis of Storm Surges in the Bay of Bengal	CPRO Computing Enterprises Inc., Victoria, B.C.	27,750
Compilation and Collation of Tsunami Records	P. Straub, Sidney, B.C.	1,403
Analysis of Seawater and Marine Air Samples from Weatherships and Other Cruises	Seakem Oceanography Limited, Sidney, B.C.	55,828
Zooplankton Sample Collection and Seawater Analysis during Two Research Cruises Conducted by the Institute of Ocean Sciences	Broccoli Bros. Enterprises, Sidney, B.C.	3,980
Collection and Compilation of Fraser Estuary and Juan de Fuca Oceanographic Data	A. Hartley, Sidney, B.C.	800
Identification of Polychaete on Rock Samples	Dobrocky Seatech Ltd., Sidney, B.C.	3,600
Compilation and Appraisal of Existing Physical Oceanographic Data in the Northwest Passage	Arctic Sciences Limited, Sidney, B.C.	17,600
Collection of Hydrographic Field Data for Updating and Correction of Navigational Charts	Coast Pilot Limited, Sidney, B.C.	90,305
An Intercomparison Study of Magnavox-Hermes AXBT Using the Front Data	Interact Computing Services Limited, Victoria, B.C.	1,700
Isotope Dilution Mass Spectrometry Analysis of Seawater Samples from the Alice Arm Area	Seakem Oceanography Limited, Sidney, B.C.	4,991
Oceanographic Data Analysis for Alice Arm Mine Tailings Dispersion Study	Interact Computing Services Limited, Victoria, B.C.	9,970
Oceanographic Support to the Institute of Ocean Sciences	Arctic Sciences Limited, Sidney, B.C.	3,000
Compilation and Filing of Oceanographic Data Collected in Coastal Waters of British Columbia	S & B Research Limited, Victoria, B.C.	8,000
Tsunami Data Computer Programming	M.M. Nugent, Victoria, B.C.	900
Variability of Winds, Temperature, Humidity and Turbulence with Height	Interact Computing Services Limited, Victoria, B.C.	11,680
Role of the Planetary Boundary Layer in Cyclogenesis over the	Atmospheric Dynamics Corp., Victoria, B.C.	7,500
Preparation and Drafting of Figures for Marine Meteorology Studies in the Pacific	B. Smith, Victoria, B.C.	1,600
Identification and Enumeration of Zooplankton Samples	Broccoli Bros. Enterprises Inc., Sidney, B.C.	7,973
Preparation of Data Listings, Maps, Graphs and Data Inventory from Three Cruises	B. Smith, Victoria, B.C.	3,910
Study of the Impact of Dumped Mud on Dungeness Crab	Archipelago Marine Research, Victoria, B.C.	11,710
Analysis and Interpretation of Atmospheric Carbon Dioxide Data	K. Pettit, Unionville, Ontario	1,000
Investigation of Arctic Industrial Offshore Activities and Ocean Dredging and Dumping in British Columbia Coastal Waters	R.H. Herlinveaux, Sidney, B.C.	13,573

Analysis of Dissolved Nutrients in Seawater	Seakem Oceanography Limited, Sidney, B.C.	8,500
Oceanographic and Technical Support for the Institute of Ocean Sciences	Seakem Oceanography Limited, Sidney, B.C.	3,000
Oceanographic and Technical Support for the Institute of Ocean Sciences	Environmental Sciences Ltd., Vancouver, B.C.	3,000
Processing of Data from a Conductivity and Temperature Recorder	Interact Computing Services Ltd., Victoria, B.C.	2,000
Investigation of the Feasibility of Mapping Chlorophyll Concentrations from Space — Phase II	University of Western Ontario, London, Ontario	53,070
A Physical/Chemical Mass Balance Study for the Beaufort Sea	Arctic Laboratories Ltd., Inuvik, N.W.T.	6,020
Study of Solar Stimulated in vivo Fluorescence by Chlorophyll a	Seakem Oceanography Ltd., Sidney, B.C.	34,997
Oceanographic Observations Aboard CSS PARIZEAU	H. Ashton, Nanaimo, B.C.	1,400
Further Development and Modifications to the Model 440 Acoustic Navigation System	Mesotech Systems Ltd., North Vancouver, B.C.	15,000
Evaluation of the Sublethal Effects of Ocean Dumped Material on Benthic Organisms in Alberni Inlet, B.C.	Seakem Oceanography Limited, Sidney, B.C.	106,684
Study of Two-Phase Flow in the Marine Riser of a Subsea Oilwell Blowout Containment System	Neotechnology Consulting Ltd, Calgary, Alberta	6,000
Development and Application of Computer Program Related to Oceanographic, Thermodynamic and Fluid/Dynamic Data	Interact Computing Services, Sidney, B.C.	11,940
Feasibility Study and Trials Associated with the Application of a Dynamic, Self-Powered, Towable Underwater Vehicle to Side Scan Sonar Surveys	Sea-I Research Limited, Sidney, B.C.	7,500
Collection of Oceanographic Data Aboard CSS PARIZEAU	H. Goldberg, Vancouver, B.C.	1,200
Identification and Enumeration of Marine Phytoplankton	E.V.S. Consultants Limited, North Vancouver, B.C.	8,421
Evaluation of the Use of Isotope Geochemistry for Tracing Heavy Metals in Marine Systems	Seakem Oceanography Limited, Sidney, B.C.	157,440
Development and Testing of Sonar Processing Techniques	Autonetics Research Associates, Sooke, B.C.	5,000
Histological Survey of Mussels from Southern Vancouver Island Waters	M.A. Cosson, Brentwood Bay, B.C.	2,100
Data Coordination and Management of Precipitation Chemistry Program	Interact Computing Services Limited, Sidney, B.C.	8,389
Analysis and Reduction of Data from Alice Arm	Interact Computing Services Limited, Sidney, B.C.	22,859
Investigation of Structure of Storms and Frontal Systems over the Northeast Pacific Ocean	Interact Computing Services Limited, Sidney, B.C.	9,024
Compilation and Appraisal of Existing Physical Oceanographic Data in Baffin Bay and the Channels of Ellesmere Island	Arctic Sciences Ltd., Sidney, B.C.	22,049
Development of Computer Programs to Process and Analyse Oceanographic Data	Interact Computing Services Limited, Sidney, B.C.	15,007
Organization of West Coast Ocean Dumping Workshops and Preparation of Annual Report	Dobrocky Seatech Ltd., Sidney, B.C.	5,115
Compilation of Marine Meteorological Data	S & B Research Limited, Victoria, B.C.	9,350
Development of a Checklist and Up-to-Date Record of Multicellular Non-endoparasitic Marine Invertebrate of the B.C. Coast	Khoyatan Marine Laboratory, Cowichan Bay, B.C	10,000
Development of a Correlation Sonar Current Meter and Ice Movement Detector	Caulfield Creative Arts Limited, Sherwood Park, Alberta	977,184
Survey of Available Physical Oceanographic Data for the Southern Island Waters of B.C.	Arctic Sciences Ltd., Sidney, B.C.	9,876
Development of Software for the Processing of Bathymetric Data	Dobrocky Seatech Ltd., Sidney, B.C.	8,647
Compilation and Collation of Tsunami Records	M. Lane, Victoria, B.C.	1,200
Compilation and Inventory of Beaufort Sea Benthos Data	E.V.S. Consultants Ltd., North Vancouver, B.C.	8,715
Technical Support for the Maintenance and Repair of Oceanographic Equipment	Tigyrll Engineering Ltd., Victoria, B.C.	10,000
Calibration of Reference Gases of Marine Carbon Research Centre Against World Meteorological Organization Standards	University of California, La Jolla, California	5,253

On Site Calibration of Marine Carbon Research Centre Infrared Carbon Dioxide Analyzer Against the World Meteorological Organization 1981 Standards	University of California, La Jolla, California	2,714
Collection of Oceanographic Data Aboard CNAV ENDEAVOUR	H. Goldberg, Vancouver, B.C.	1,200
Synoptic Aircraft Based Oceanographic Survey of the Arctic Archipelago	Arctic Sciences Ltd., Sidney, B.C.	128,894
Compilation and Appraisal of Existing Chemical Oceanographic Data in the Northwest Passage	Arctic Laboratories Limited, Sidney, B.C.	17,550
Preparation of Oceanographic Data and Scientific Diagrams Using Data from Charts, Tables and Records	C. Wallace, Sidney, B.C.	9,750
Compilation of Arctic Physical and Chemical Oceanographic Data Reports	Arctic Sciences Limited, Sidney, B.C.	46,772
Development of isolation and separation procedures and histopathological examination of mussels	Seakem Oceanography Limited, Sidney, B.C.	30,313
Drafting and photographic services	Techni-Graphics, Victoria, B.C.	4,500
Study of the Measurements of Winds over Coastal Waters by Acoustic Remote Sensing	Arctic Sciences Limited, Sidney, B.C.	142,257
Statistical Analysis of Survey Data in the Beaufort Sea	Barrodale Computing Services Limited, Victoria, B.C.	6,000
Study of Plankton-Feeding Alcids	M. Galbraith, Victoria, B.C.	1,300
Identification and Enumeration of Zooplankton Samples from Alice Arm	Edward Anderson Marine Sciences, Victoria, B.C.	3,706
Study of Plankton of the Beaufort Sea	MacLaren Plansearch Inc., Vancouver, B.C.	9,670
Numerical Modelling Studies of the Estuarine Circulation in the Strait of Georgia System — Phase IV	University of British Columbia, Vancouver, B.C. (Dr. R. Burling)	19,000
The Sedimentation of Mine Tailings in a Marine Environment — Phase I	Capital Applied Research & Technology Ltd., Victoria, B.C.	38,382

APPENDIX II
PUBLICATIONS

A. Department of Fisheries and Oceans

(1) Pacific Marine Science Reports

PMSR 81-1	Crawford, W.R., and T.R. Osborn	*Turbulence in the Equatorial Pacific Ocean*
MSR 81-2	Byers, S.C., Dobrocky Seatech Ltd. (ed.)	*Report on Ocean Dumping R & D Pacific Region Department of Fisheries and Oceans 1979-80*
PMSR 81-3	Whitney, F.A., K. Perry, C. Philpott, A. Ramey, and C.S. Wong	*Pentachlorophenol in a Pelagic Marine Ecosystem; Effects on the Ecosystem*
PMSR 81-4	Giovando, L.F., and R.H. Herlinveaux	*A Discussion of Factors Influencing Dispersion of Pollutants in the Beaufort Sea*
PMSR 81-5	Brown, R.E.	*Designing, Building and Maintaining the Langara Point Tsunami Warning Station 1968-1980*
PMSR 81-6	Giovando, L.F.	*Observations of Seawater Temperature and Salinity at Cape Beale Lightstation and Bamfield Marine Station 1969-1977*

PMSR 81-7	Papadakis, J.E.	*A Simple Method for Monotonic Approximation of Functions*
PMSR 81-8	Woodward, M.J.	*A Long Life Battery for a One-Quarter Watt Pinger*
PMSR 81-9	Papadakis, J.E.	*Determination of the Oceanic Wind Mixed Layer Depth by an Extension of Newton's Method*
PMSR 81-10	Thomson, Richard E.	*An Analysis of Wind and Current Observations Collected in the Queen Charlotte Sound - Hecate Strait - Dixon Entrance Region during 1954 and 1955*
PMSR 81-11		*Oceanographic Observations at Ocean Station P, 5 January - 15 February, 1979, Volume 97*
PMSR 81-12		*Oceanographic Observations at Ocean Station P, 9 February - 29 March, 1979, Volume 98*
PMSR 81-13		*Oceanographic Observations at Ocean Station P, 23 March - 10 May, 1979, Volume 99*
PMSR 81-14		*Oceanographic Observations at Ocean Station P, 4 May - 21 June, 1979, Volume 100*
PMSR 81-15		*Oceanographic Observations at Ocean Station P, 15 June - 2 August, 1979, Volume 101*
PMSR 81-16		*Oceanographic Observations at Ocean Station P, 27 July - 13 September, 1979, Volume 102*
PMSR 81-17		*Oceanographic Observations at Ocean Station P, 7 September - 25 October, 1979, Volume 103*
PMSR 81-18		*Oceanographic Observations at Ocean Station P, 19 October - 6 December, 1979, Volume 104*
PMSR 81-19		*Oceanographic Observations at Ocean Station P, 30 November, 1979 - 17 January, 1980, Volume 105*
PMSR 81-20	Thomson, R.E., and W.S. Huggett	*Wind-Driven Inertial Oscillations Within Queen Charlotte Sound and Hecate Strait, May-September 1977*
PMSR 81-21	Whitney, F.A., C.L. Philpott, H. Seki and C.S. Wong	*The Effects of Copper and Copper Plus Glucose on an Enclosed Marine Ecosystem*
PMSR 81-22	Huggett, W.S., and M.J. Woodward	*Tidal Currents in Johnstone Strait*
PMSR 81-23	Giovando, L.F.	*Observations of Seawater Temperature and Salinity at British Colulmbia Shore Stations, 1979*

(2) Contractor Report Series

CRS 81-1	Borstad, G.A., and R.M. Brown, Seakem Oceanography Ltd.	*Airborne Remote Sensing of Sea Surface Chlorophyll and Temperature Along the Outer British Columbia Coast*
CRS 81-2	Brown, R.M., and G.A. Borstad	*Canada-France Ocean Optics Experiment: Sea Truth Data for Stations in British Colulmbia Waters*
CRS 81-3	Shearer, Jim, Consultant, Ottawa and Lauchie Meagher, Geomarine Assoc. Ltd., Halifax	*Pingo Correlation and Prediction Study*
CRS 81-4	Krauel, D.P., Woodward-Clyde Consultants	*Deep Water Flow and Exchange Processes in Alice Arm, B.C.*

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APPENDIX III

PERMANENT STAFF, 1981

Institute of Ocean Sciences

A. Department of Fisheries and Oceans

Director-General

Mann, C.R.; B.Sc., M.Sc. (N.Z.), Ph.D. (Brit. Col.), D.Eng. (N.S. Tech.), FRSC

Management Services Division

Chief of Division:

Todd, N.A.; B.Sc. (Glasgow), M.A. (Carleton)

Adamson, G.
*Batchelor, R.J.
*Bell, S.E.
Clapp, L.A.
Coldwell, J.H.
Cooper, B.J.
*Craton, M.I.K.
Curtis, J.N.
Deane, G.J.
Delacretaz, A.
Denney, C.E.
Doxey, K.
Doyle, D.A.
Drysdale, A.E.
Firth, C.
Grills, C.J.
*Hall, E.J.
Keding, L.M.
*Lackner, R.C.
Lafortune, A.J.; B.A. (Manitoba)
*Lalonde, M.T.
Lapp, B.I.; B.A. (Victoria)
Lohrmann, B.A.; B.Sc. (Guelph)
Mathias, A.L.
McKenzie, S.D.
Oakfield, C.L.
Parsons, J.E.
Peirson, E.
Poulin, J.G.
*Reinstein, H.G.
Sabourin, J.T.
*Simington, V.L.
Thomson, L.S.C.; B.A. (Sask), B.L.S. (B.C.)
Tillie, D.G.
Van Dusen, T.S.
Van Eyk, W.J.
*Wonnacott, D.C.

**Left during 1981*

Commissionaires

Sgt. W.L. Caldwell
Sgt. D.W. Price
*Comm. G. Bradshaw
Comm. J. Quinton
Comm. L. Trerice
Comm. P. Osborne
*Comm. J. Stewart
*Comm. G. Armstrong
Comm. H. Moffat
*Comm. J. Selman
*Comm. B. Ashton
Comm. R. Alcock
Comm. J. Redden
Comm. J Holliger

Personnel

Regional Personnel Manager:

Hamilton, K.R.: B.A. (Brit. Col.)

Knapp, B.M.
Olauson, E.J.
Smith, C.S.
Stevens, I.B.; CIMA (McMaster)
Wenezenki, L.B.

Hydrographic Division

Director of Hydrography

Bolton, M.; C.L.S.

Ages, A.B.; B.A.Sc., M.A.Sc. (Brit. Col.), P.Eng.
**Bastarache, M.; Dip. BCIT

Bell, R.D.
*Brown, M.
*Brown, R.E.
Browning, P.C.
*Chan, G.L.
Chapeskie, R.
Coldham, F.A.
Crawford, W.R. B.Sc., M.A.Sc. (Waterloo), Ph.D. (Brit. Col.)
Crowley, J.V.; C.L.S.
Crowther, W.S.; CC (Ont. Inst. of Chartered Cartographers)
Curran, T.A.; B.A.Sc. (EE), M.Sc. (Brit. Col.), P.Eng.
Czotter, K.L.; Dip. BCIT
Dobson, D.C.
Dorosh, L.W.; Dip. BCIT
Dow, A.J.; P.Eng. (UNB)
Earl, E.L.P.
Eaton, G.H.; Dip. BCIT, B.Sc. (UNB)
Ellison, G.
Farmer, M.
Fisher, D.L.
Galloway, J.L.; B.A.Sc. (EE), M.A.Sc. (EE) (Brit. Col.), P.Eng.
Gould, J.
*Gregson, D.J.; Dip. BCIT
Halcro, K.; Dip. BCIT
Harrison, D.
Hermiston, F.V.
Hinds, E.W.; Dip. BCIT
Hohl, M.
Hollinger, C.; Dip. BCIT
Holman, K.R.
Huggett, W.S.; Master (FG)
**Jackson, D.
Jennings, M.
Johnson, B.A.; Dip. BCIT
Kenny, B.
Kidson, G.
Korhonen, R.K.
Larkin, J.B.; B.Sc. (PEI)
Lee, K.S.
Loschiavo, R.; Dip. BCIT
Lusk, B.M.; Master, (350 T), C.L.S.
**Lyngberg, K.; Dip. BCIT
Lyon, A.G.
McKenzie, S.D.
Ma, A.C.; B.Sc. (Victoria)
*Mikkelson, M.
Milner, P.R.; Dip. BCIT
Moody, A.E.
Mortimer, A.R.; Master, (FG), B.Sc. (Victoria), C.L.S.
Muse, R.A.; Trade Cert. CAF
O'Connor, A.D.; Mate (HT) (U.K.), Master (350T), C.L.S.
Osborne, M.
Parks, J.R.; B.A.Sc. (EE) (Brit. Col.)
Patton, M.M.
**Pfluger, H.
Philp, A.R.
Pickell, L.M.
Pierce, R.A.
Pite, H.
Popejoy, R.D.
Rapatz, W.J.; B.Sc. (Victoria)
Raymond, A.R.; Dip. (Algonquin College)
Richardson, G.E.
Roberts, J.N.; Master (FG), Cdr. RCN (Ret'd.)
Ross, A.D.; CC (Ont. Inst. of Chartered Cartographers)
Sandilands, R.W.; Lt. (H) RN (Ret'd.) FRGS
Sargent, E.D.; Dip. BCIT
Schofield, A.
Smedley, A.J.; LCdr. RCN (Ret'd.)
****Smith, G. R.; B.A.Sc. (ME) (Brit. Col.), P. Eng.
Smith, A.; Master (FG)
Steeples, J.; Cert. Mech. Eng. (Edinburgh)
Stephenson, F.E.; B.Sc. (Victoria)
*Tamasi, C.R.; Dip. BCIT
Taylor, R.G.
Taylor, W.R.; Dip. RCC
**Thompson, A.; Dip. BCIT
Thompson, L.G.
Van Duin, W.P.; Dip. BCIT
Vosburgh, J.A.; Dip. BCIT
Wakefield, L.M.
Ward, M.M.; Dip. BCIT, B.A. (Geog.)
Watt, B.M.
Watt, J.V.; B.A.Sc. (EE) (Brit. Col.), P.Eng.
Whincup, G.
Wigen, S.O.; B.A.Sc. (Brit. Col.), P.Eng.
***Woods, M.V.; Dip. BCIT
Woodward, M.J.; B.Sc. (Victoria), M.Sc. (Toronto)
Yee, J.

*_Left during 1981_
**_Joined during 1981_
***_Educational leave_
****_On Interchange Program_

Ship Division

Parkinson, R.W. Engineer 1st Class Combined. Assistant Marine Superintendent (Engineering). Member, Institute of Marine Engineers.
Acting Appointment Regional Marine Superintendent

Fitch, L.A.H.; Master H.T.; Assistant Marine Superintendent (Deck)
Smith, F.V.; Marine & Industrial Electrician; Depot Supervisor.
Periera, P.; Engineer 1st Class Motor. Relief Chief Engineer
Craton, M.; Administration Clerk

CSS PARIZEAU

Newton, B.L.; Master F.G.; Master
Buchan, J.; Master F.G.; 1st Officer
Butler, K.; Master F.G.; 2nd Officer
Parlmer, S.; Supply Officer
Olcen, P.; Engineer 1st Class Motor, Chief Engineer
Trant, R.; Engineer 3rd Class Motor, Senior 2nd Engineer
Andersen, A.; Engineer 3rd Class Steam, 4th Class Motor, 2nd Engineer
Stanway, J.D.; Engineer 4th Class Motor, 3rd Engineer
Greening, M.; Engineer 4th Class Motor, 4th Engineer

CSS RICHARDSON

McKenzie, R.; Master H.T.; Master
Burrell, R.; Engineer 4th Class Motor, Chief Engineer

M.V. PANDORA II (Charter)

Jones, R.; Master

CSS VECTOR

Sjoholm, K.; Master F.G.; Master
Wheeler, M.G.; Master H.T.; 1st Officer
Campbell, J.; Mate H.T.; 2nd Officer
Pearson, R.; Engineer 3rd Class Motor, Chief Engineer
Douglas, D.; Engineer 4th Class Motor, 2nd Engineer

PISCES IV

Chambers, F.J.; Chief Pilot
Taylor, R.H.; Pilot
Witcombe, A.; Pilot
Oszust, J.; Pilot
Thomas, G.; Pilot
Shepherd, K.; Pilot

Ocean Information

Chief of Division:

Cornford, A.B.; B.Sc. (McMaster), Ph.D. (Brit. Col.)

Smiley, B.D.; B.Sc., M.Sc. (Alberta)

Ocean Chemistry Division

Chief of Division:

Wong, C.S.; B.Sc., M.Sc. (Hong Kong), Ph.D. (Scripps), Dip. Mar. Sc. (UNESCO), FRSC (U.K.)

Bellegay, R.D.; Dip. NAIT, Assoc. Deg. in Oceanography (Shoreline Community College, Seattle)
Cretney, W.J.; B.Sc., Ph.D. (Brit. Col.)
Johnson, W.K.; Dip. BCIT
Macdonald, D.M.; B.A.Sc. (Brit. Col.)
Macdonald, R.W.; B.Sc., Ph.D. (Dalhousie)
McLaughlin, F.A.; B.Sc. (Victoria)
*Munro, P.S.; B.Sc. (Queen's)
Paton, D.W.; B.Sc. (Brit. Col.)
**Smith, G.L.; Dip. NAIT
Soutar, T.J.; Dip. BCIT
Thompson, J.A.J.; B.Sc. (McMaster), Ph.D. (Alberta)
Whitney, F.A.; B.Sc. (Brit. Col.)

**Left in 1981*
***Joined in 1981*

Ocean Physics Division

Chief of Division:

Garrett, J.F.; B.A. (Harvard), Ph.D. (Brit. Col.)

Bell, W.H.; B.A.Sc. (Brit. Col.), M.Sc. (Hawaii), P.Eng.
Bigham, R.W.
Chase, G.W.; Dip. BCIT
Cooke, R.A.; Dip. RCC
Crean, P.B.; B.Sc. (Dublin), M.A.Sc. (Toronto), Ph.D. (Liverpool)
de Jong, C.
Farmer, D.M.; B.Com., M.Sc. (McGill), Ph.D. (Brit. Col.)
**Francis, D.B.; B.Sc. (Victoria)
Freeland, H.J.; B.A. (Essex), Ph.D. (Dalhousie)
Gargett, A.E.; B.Sc. (Manitoba), Ph.D. (Brit. Col.)
Giovando, L.F.; B.A., M.A., Ph.D. (Brit. Col.)
Gower, J.F.R.; B.A., M.A., Ph.D. (Cantab)
Henry R.F.; B.Sc. (Edinburgh), Ph.D. (Cantab)
Johnston, P.
Kamitakahara, G.R.; B.Sc. (Toronto)
Koppel, A.W.
Kimber, P.M.
Kuwahara, L.S.C.; B.Sc. (Brit. Col.)
Lake, R.A.; B.Sc. (Brit. Col.), M.Sc. (Washington)
Lee, A.Y.P.; B.Sc. (Victoria)
Lewis, E.L., B.Sc., M.Sc., Ph.D. (London)
Love, J.
McNeill, J.M.
Meikle, J.H.
Melling, H.; B.Sc., M.Sc., Ph.D. (Toronto)
Minkley, B.G., Dip. BCIT
Miyake, M.; B.S. (EE) (Drexel), M.S., Ph.D. (Washington)
Moorhouse, S.W.
Murty, T.S.; B.Sc., M.Sc. (Andhra), M.S., Ph.D. (Chicago)

Perkin, R.G.; B.A.Sc., M.Sc. (Brit. Col.)
Richards, D.L.
Spearing, L.A.F.; B.Sc. (Brit. Col.)
Stickland, J.A.
Stucchi, D.J.; B.A.Sc. (York), M.Sc. (Dalhousie)
Sudar, R.B.; B.A.Sc. (Toronto)
Tabata, S.; B.A., M.A. (Brit. Col.), D.Sc. (Tokyo)
Teichrob, R.C.; Dip. BCIT
Thomson, R.E.; B.Sc., Ph.D. (Brit. Col.)
Topham, D.R.; D.L.C., D.C.A.E., Ph.D. (Loughborough)
Wallace, J.S.

***Joined in 1981*

Computing Services

Head:

Teng, K.; B.A.Sc., M.A. (Brit. Col.)

*Butcher, J.W.; B.Sc. (Victoria), M.Sc. (Toronto)
Douglas, A.N.; B.Sc. (Victoria)
Foreman, M.G.; B.Sc. (Queen's), M.Sc. (Victoria)
Johns, R.E.; B.Sc. (Victoria), M.Sc. (Brit. Col.)
Lee, D.K.; B.S. (Chosun-Korea), M.S. (Oregon)
Lee, K.S.; B.Sc. (Victoria)
Linguanti, J.; B.Sc. (Victoria)
***Ma, A.C.; B.Sc. (Victoria)
Oraas, S.R.; B.A.Sc., M.A.Sc. (Brit. Col.)
Page, J.S.; B.Sc. (Brit. Col.)
Smith, L.J.; B.Sc. (Simon Fraser)
Wharton, A.H.; B.Sc. (Victoria)
Woollard, A.L.; B.Sc. (Victoria)

**Left in 1981*
****Transferred from Hydrography Division*

Ocean Ecology Division

Chief of Division:

Brinkhurst, R.O.; B.Sc., Ph.D., D.Sc. (London)

*Coastes, K.; B.Sc. (Toronto), M.Sc. (Victoria)
Denman, K.L.; B.Sc. (Calgary), Ph.D. (Brit. Col.)
Forbes, R.; B.Sc. (Carleton), M.Sc. (Alberta)
Hill, S.H.; B.Sc. (Brit. Col.), M.Sc. (Victoria)
Mackas, D.L.; B.S., M.S. (Washington), Ph.D. (Dalhousie)
**Stone, M.

**Left in 1981*
***Joined in 1981*

B. Department of the Environment

Atmospheric Environment Service

McBean, G.A.; B.Sc. (Brit. Col.), M.Sc. (McGill), Ph.D. (Brit. Col.)

Canadian Wildlife Service

Vermeer, K.; M.Sc. (Brit. Col.), Ph.D. (Alberta)

C. Department of Energy, Mines and Resources

Pacific Geoscience Centre

Chief Scientist:

*Milne, W.G.; B.A. (Toronto), M.A. (California), Ph.D. (U. of Western Ontario)

Administrative Group

Fyfe, K.; Head
Chisholm, D.M.

Technical Support Group

Bone, M.N.; Head, B.A.Sc. (Toronto)
Bennetts, H.J.
Bunyan, T.C.
Whitford, H.A.

Marine Geology and Geophysics Section

Yorath, C.J.; Head, B.S.C. (Brit. Col.), M.Sc. (Alberta), Ph.D. (Queen's)
Bornhold, B.C.; B.Sc. (Waterloo), M.A. (Duke), Ph.D. (M.I.T. — Woods Hole)
Cameron, B.E.B.; B.Sc., M.Sc. (Alberta)
Currie, R.G.; B.Sc., M.A.Sc. (Brit. Col.)
**Forbes, T.; B.Sc. (Simon Fraser)
Frydecky, I.I.; B.A.Sc., M.A.Sc. (Brit. Col.), P.Eng.
**Hamilton, T.; B.Sc. (Case Western Reserve), A.M. (Indiana), Ph.D. (Alberta)
**Hill, W.
**Jewsbury, G.C.; B.Sc. (Victoria)
**Johns, M.; B.Sc. (Brit. Col.)
Luternauer, J.L.; B.A. (Colby), M.A. (Duke), Ph.D.(Brit. Col.)
McLaren, P.; B.Sc., M.Sc. (Calgary), Ph.D. (South Carolina)
**Mangin, M.; B.Sc. (Brit. Col.)
*Sarracino, L.
*Seemann, D.; B.Sc. (Brit. Col.)

Geodynamics Group

Dragert, H.; Head, B.Sc. (Toronto), M.Sc.,
Ph.D. (Brit. Col.)

Geomagnetic Group

Law, L.K.; Head, B.A.Sc. (Toronto),
M.Sc. (U. of Western Ontario), Ph.D. (Cantab)
Auld, D.R.; B.A.Sc. (Brit. Col.)
DeLaurier, J.M.; B.Sc. (Queen's)
**Irving, E.; M.A., Sc.D. (Cantab.), D.Sc. (Hon. Carleton),
FRSC, FRS
**Kari, C.M.; B.Sc. (Carleton)

Geothermal Group

Lewis, T.L.; Head, B.A.Sc., M.Sc. (Brit. Col.),
Ph.D. (U. of Western Ontario)

Gravity Group

Riddihough, R.P.; Head, B.Sc. (Kings College, London),
DIC, M.Sc. (Imperial Col., London),
Ph.D. (U. of London)
Price, W.
**Seemann, D.; B.Sc. (Brit. Col.)
**Sweeney, J.F.; B.A., M.A., Ph.D. (S.U.N.Y., Buffalo)

Seismic Hazards

Weichert, D.H.; Head, B.A.Sc., M.Sc., Ph.D. (Brit. Col.)
Gregory, J.J.
Rogers, G.C.; B.Sc. (Brit. Col.), M.Sc. (U. of Hawaii)
**Horner, R.; B.Sc. (Manitoba)

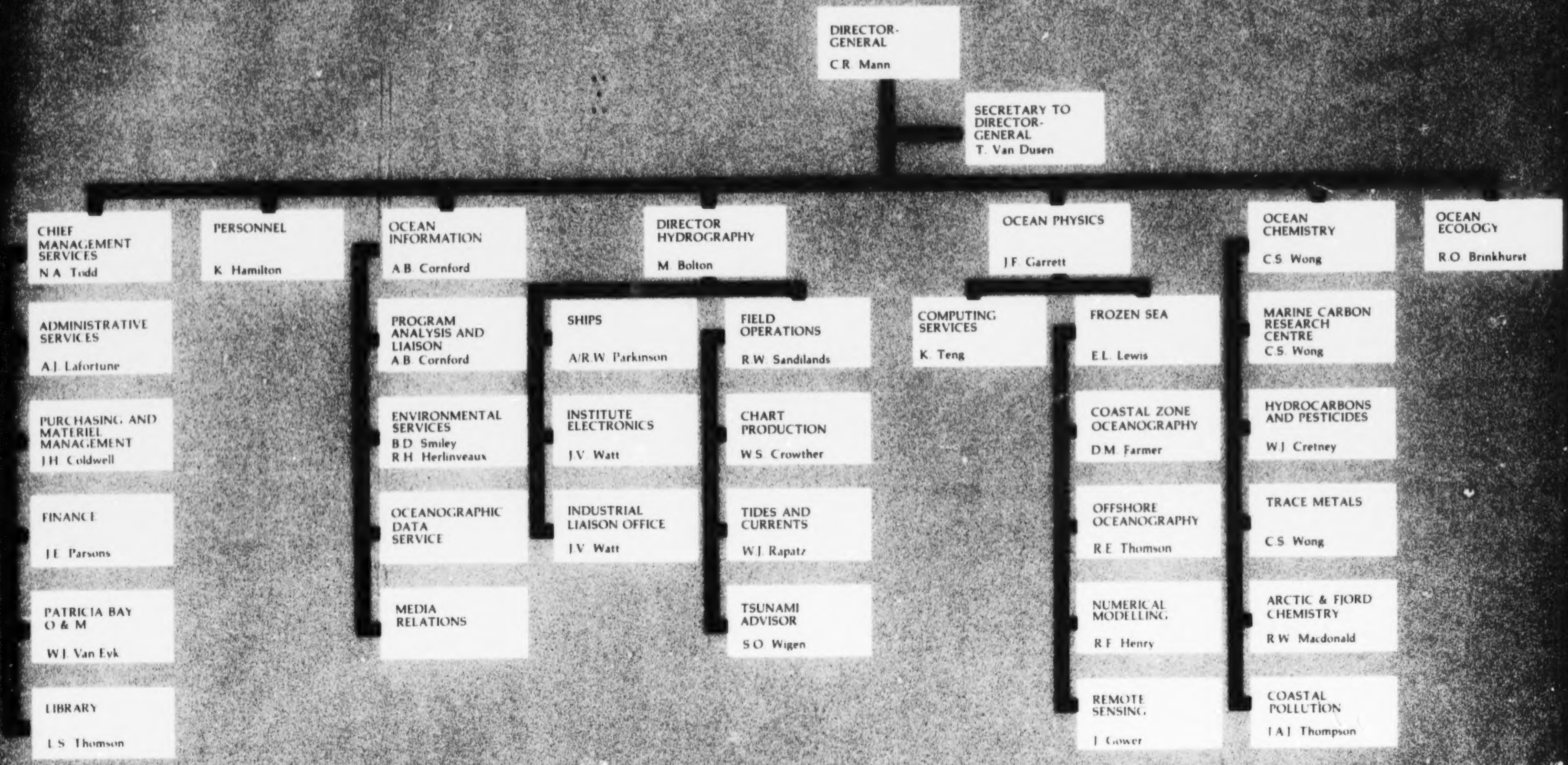
Seismic Structure

Hyndman, R.D.; Head, B.A.Sc., M.A.Sc. (Brit. Col.),
Ph.D. (A.N.U.)
McMechan, G.A.; B.A.Sc. (Brit. Col.), M.Sc. (Toronto)

**Left during 1981*
***Joined during 1981*

Organization Chart

Department of Fisheries and Oceans



- DIRECTOR-GENERAL C.R. Mann
  - SECRETARY TO DIRECTOR-GENERAL T. Van Dusen
  - CHIEF MANAGEMENT SERVICES N.A. Todd
    - ADMINISTRATIVE SERVICES A.J. Lafortune
    - PURCHASING AND MATERIEL MANAGEMENT J.H. Coldwell
    - FINANCE J.E. Parsons
    - PATRICIA BAY O & M W.J. Van Eyk
    - LIBRARY L.S. Thomson
  - PERSONNEL K. Hamilton
  - OCEAN INFORMATION A.B. Cornford
    - PROGRAM ANALYSIS AND LIAISON A.B. Cornford
    - ENVIRONMENTAL SERVICES B.D. Smiley, R.H. Herlinveaux
    - OCEANOGRAPHIC DATA SERVICE
    - MEDIA RELATIONS
  - DIRECTOR HYDROGRAPHY M. Bolton
    - SHIPS A/R.W. Parkinson
    - INSTITUTE ELECTRONICS J.V. Watt
    - INDUSTRIAL LIAISON OFFICE J.V. Watt
    - FIELD OPERATIONS R.W. Sandilands
    - CHART PRODUCTION W.S. Crowther
    - TIDES AND CURRENTS W.J. Rapatz
    - TSUNAMI ADVISOR S.O. Wigen
  - OCEAN PHYSICS J.F. Garrett
    - COMPUTING SERVICES K. Teng
    - FROZEN SEA E.L. Lewis
    - COASTAL ZONE OCEANOGRAPHY D.M. Farmer
    - OFFSHORE OCEANOGRAPHY R.E. Thomson
    - NUMERICAL MODELLING R.F. Henry
    - REMOTE SENSING J. Gower
  - OCEAN CHEMISTRY C.S. Wong
    - MARINE CARBON RESEARCH CENTRE C.S. Wong
    - HYDROCARBONS AND PESTICIDES W.J. Cretney
    - TRACE METALS C.S. Wong
    - ARCTIC & FJORD CHEMISTRY R.W. Macdonald
    - COASTAL POLLUTION J.A.J. Thompson
  - OCEAN ECOLOGY R.O. Brinkhurst